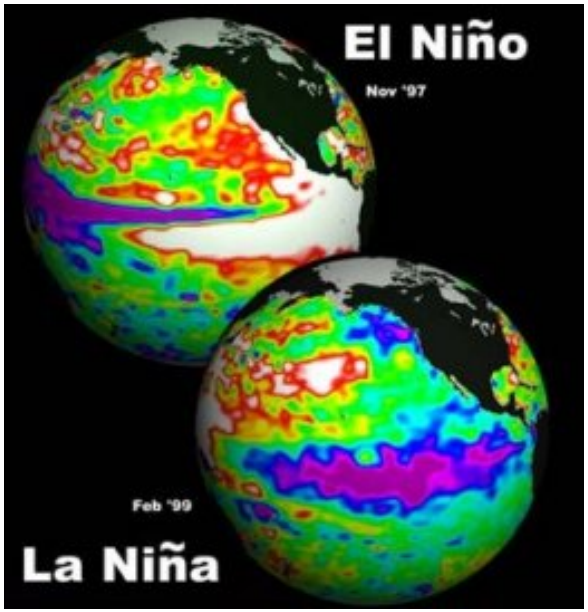
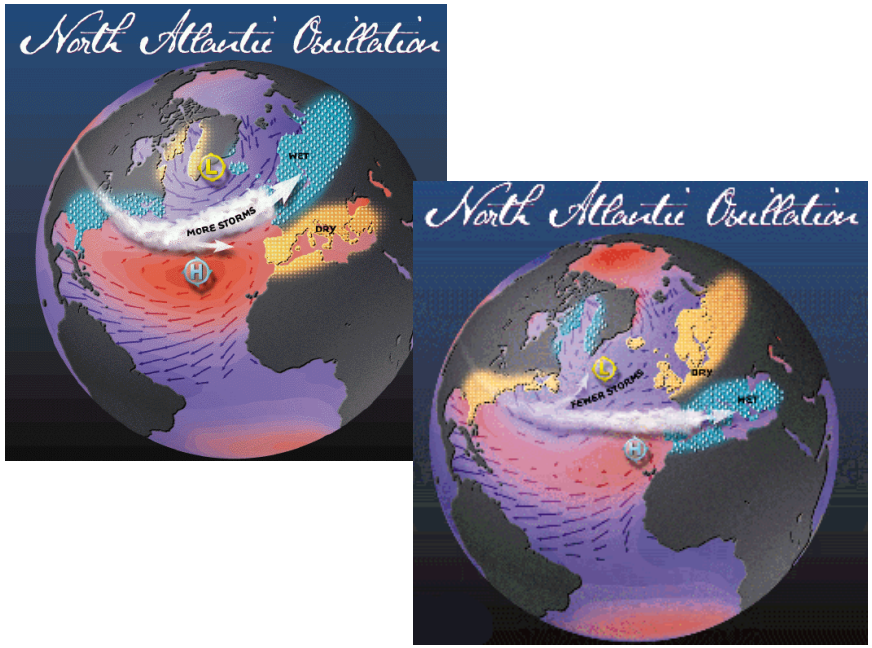
Alma Mater Studiorum Università di Bologna
sede di Ravenna
Laurea Triennale in Scienze Ambientali
Corso: Climatologia
Marco.Zavatarelli@unibo.it

ENSO & NAO

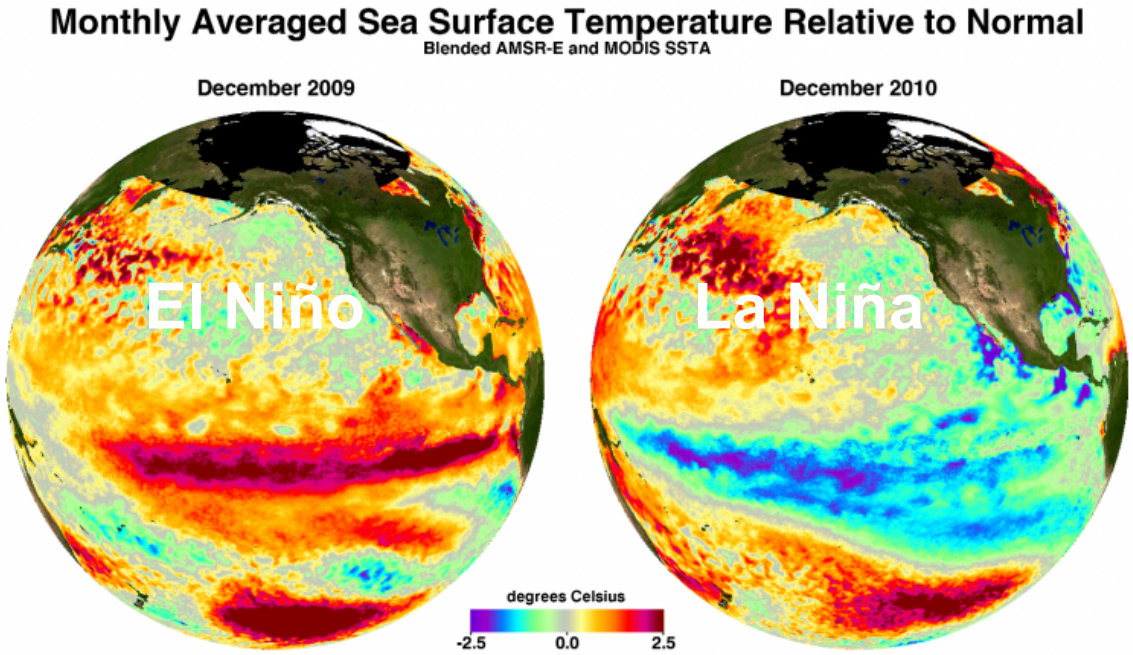
Variabilità climatica a breve termine





El Niño Southern Oscillation: ENSO

ENSO la maggiore variazione interannuale delle caratteristiche del sistema accoppiato Oceano-Atmosfera.



Anomalia della temperatura Superficiale dell' oceano Pacifico per la fase "Calda" (El Niño) e "fredda" (La Niña)

El Niño: la componente Oceanica

The Definition of El Niño

Kevin E. Trenberth
National Center for Atmospheric Research,* Boulder, Colorado

L'origine del nome:

2. El Niño definitions

The term "El Niño" originally applied to an annual weak warm ocean current that ran southward along the coast of Peru and Ecuador about Christmastime (hence Niño, Spanish for "the boy Christ-child") and only subsequently became associated with the unusually large warmings that occur every few years and change the local and regional ecology. The coastal warming, however, is often associated with a much more extensive anomalous ocean warming to the international date line, and it is this Pacific basinwide phenomenon that forms the link with the anomalous global climate patterns.

...the sea is full of wonders, the land even more so.
First of all the desert becomes a garden ....
The soil is soaked by the heavy downpour, and within a few weeks the whole country is covered by abundant pasture.
The natural increase of flocks is practically doubled and cotton can be grown in places Where in other years vegetation seems impossible.

— From Mr. S. M. Scott & Mr. H. Twiddle quoted from Murphy (1926).

El Niño: la componente Oceanica

The Definition of El Niño

Kevin E. Trenberth
National Center for Atmospheric Research,* Boulder, Colorado

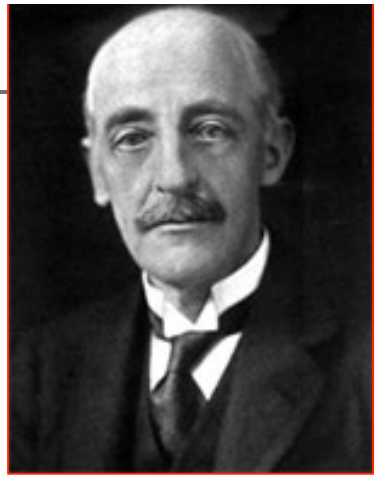
La definizione attuale (molto più ampia)

El Niño \ 'el nē' nyō *noun* [Spanish] \ 1: The Christ Child 2: the name given by Peruvian sailors to a seasonal, warm southward-moving current along the Peruvian coast <la corriente del Niño> 3: name given to the occasional return of unusually warm water in the normally cold water [upwelling] region along the Peruvian coast, disrupting local fish and bird populations 4: name given to a Pacific basin-wide increase in both sea surface temperatures in the central and/or eastern equatorial Pacific Ocean and in sea level atmospheric pressure in the western Pacific (Southern Oscillation) 5: used interchangeably with ENSO (El Niño–Southern Oscillation) which describes the basin-wide changes in air–sea interaction in the equatorial Pacific region 6: ENSO warm event *synonym* warm event *antonym* La Niña \ [Spanish] \ the young girl; cold event; ENSO cold event; non-El Niño year; anti-El Niño or anti-ENSO (pejorative); El Viejo \ 'el vyā hō\ noun [Spanish] \ the old man.

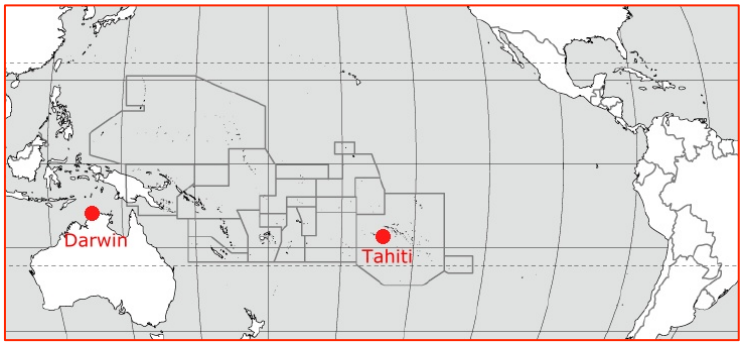
Southern Oscillation: la componente atmosferica

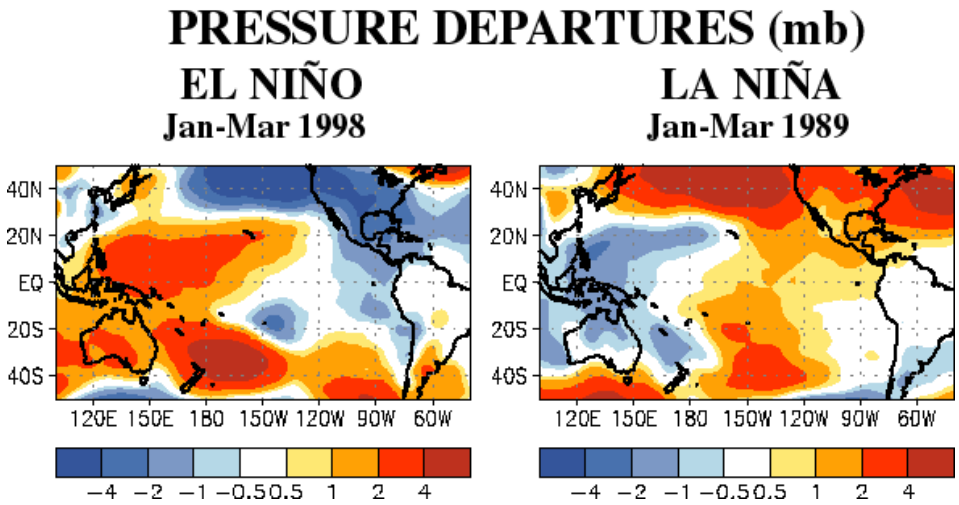
El Niño Southern Oscillation (ENSO)☆

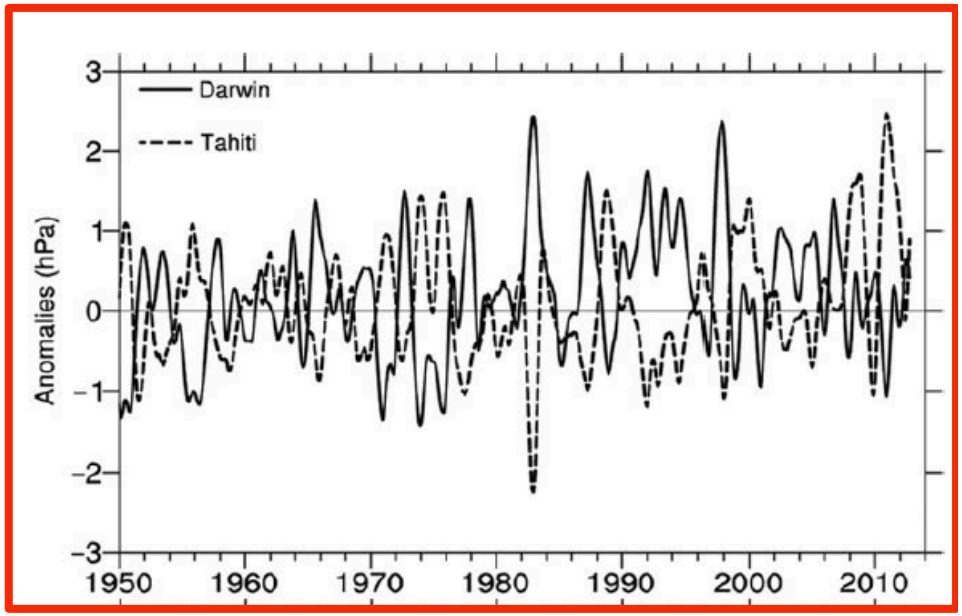
KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA



Nel 1910 Sir Gilbert Walker identificò una relazione inversa fra la pressione Atmosferica misurata a Tahiti e a Darwin (Australia) che definì come "Southern Oscillation (**SO**)" (Oscillazione Meridionale)







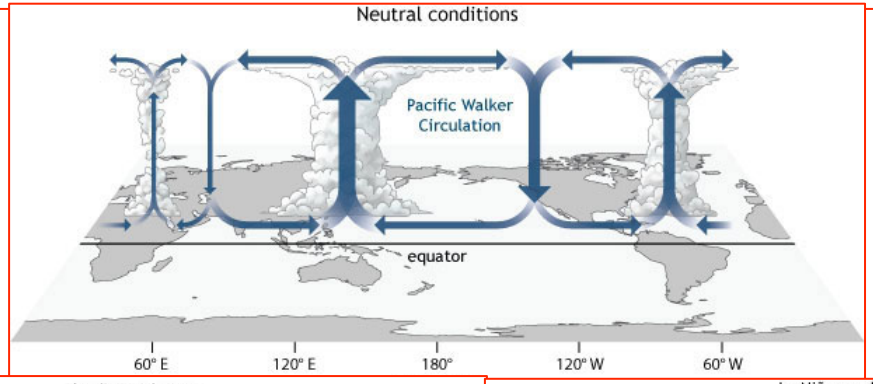
Anomalia della pressione atmosferica a Darwin e Tahiti

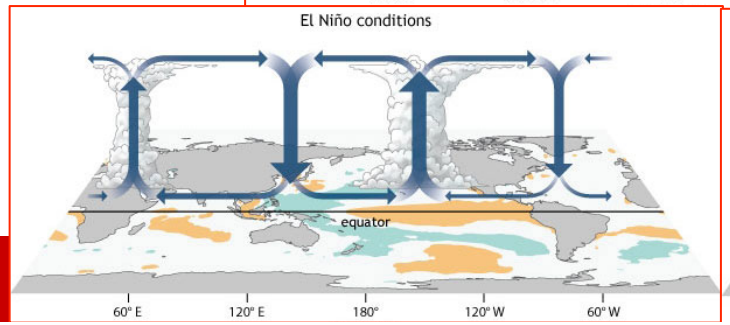
Southern Oscillation: la componente atmosferica

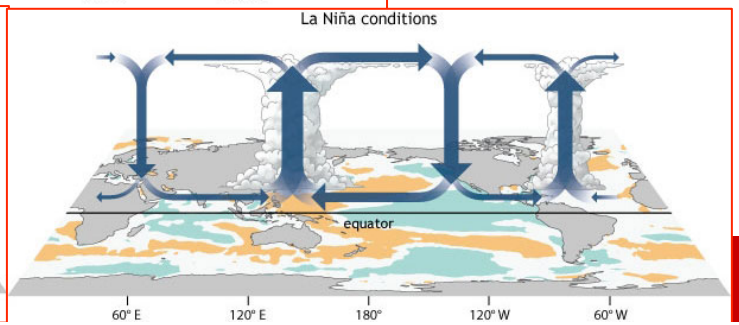
La circolazione di Walker

The **Walker circulation**, also known as the **Walker cell**, is a conceptual model of the air flow in the tropics in the lower atmosphere (troposphere). According to this model, parcels of air follow a closed circulation in the zonal and vertical directions. This circulation, which is roughly consistent with observations, is caused by differences in heat distribution between ocean and land. It was discovered by Gilbert Walker. In addition to motions in the zonal and vertical direction the tropical atmosphere also has considerable motion in the meridional direction as part of, for example, the Hadley Circulation.

El Niño/La Niña è associato a variazioni nella posizione della Cella di Walker
Corrispondenti a variazioni della differenza di pressione fra Darwin e Tahiti







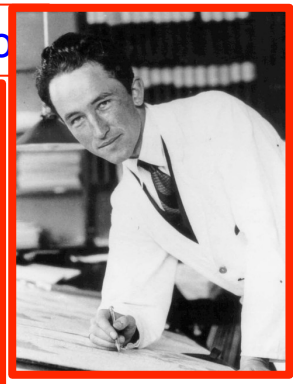
ENSO: Variazione del sistema accoppiato

MONTHLY WEATHER REVIEW
VOLUME 97, NUMBER 3
MARCH 1969

ATMOSPHERIC TELECONNECTIONS FROM THE EQUATORIAL PACIFIC

J. BJERKNES
Department of Meteorology, University of California, Los Angeles, Calif.

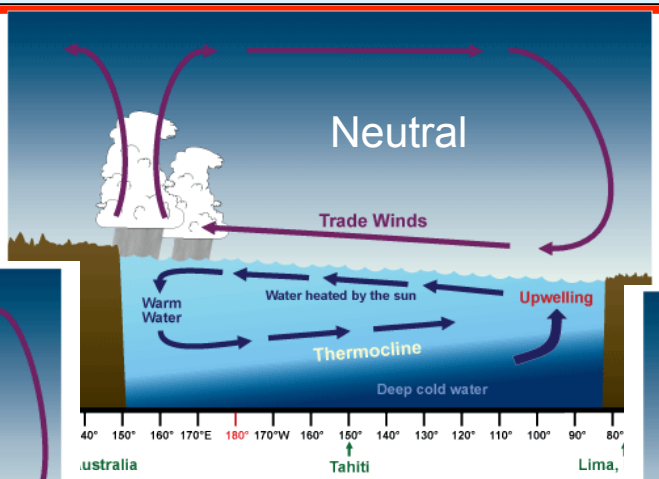
Jakob Bjerknes stabilì (1969) che El Niño NON era un fenomeno puramente Oceanico

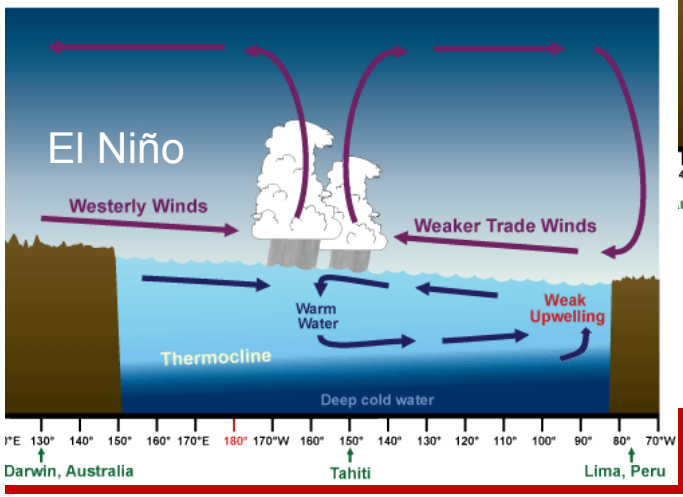


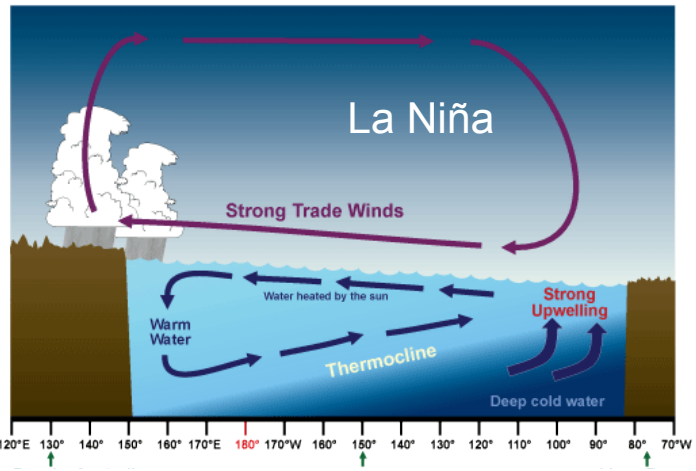
ABSTRACT

The "high index" response of the northeast Pacific westerlies to big positive anomalies of equatorial sea temperature, observed in the winter of 1957–58, has been found to repeat during the major equatorial sea temperature maxima in the winters of 1963–64 and 1965–66. The 1963 positive temperature anomaly started early enough to exert the analogous effect on the atmosphere of the south Indian Ocean during its winter season.

The maxima of the sea temperature in the eastern and central equatorial Pacific occur as a result of anomalous weakening of the trade winds of the Southern Hemisphere with inherent weakening of the equatorial upwelling. These anomalies are shown to be closely tied to the "Southern Oscillation" of Sir Gilbert Walker.





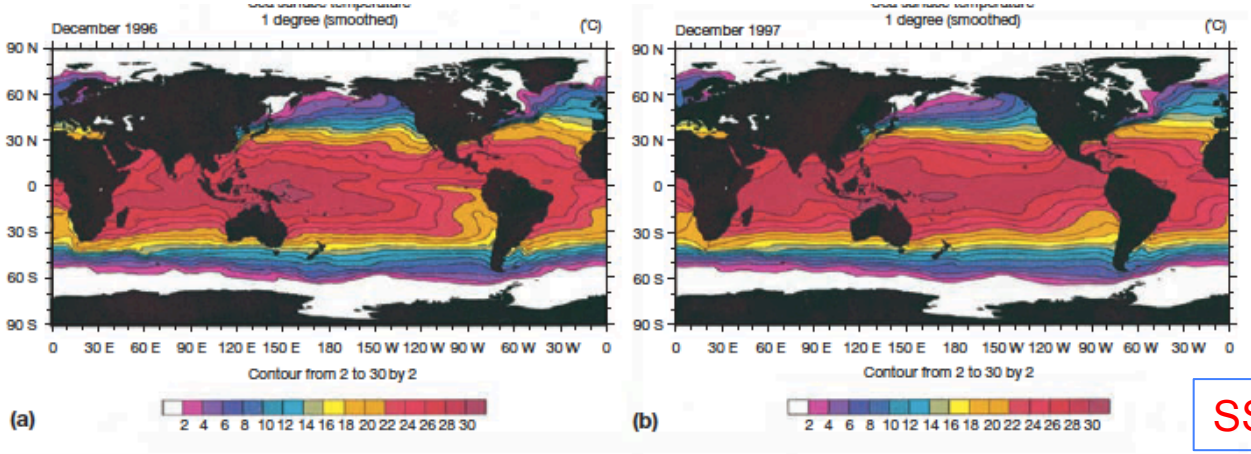


Eventi ENSO

El Niño Southern Oscillation (ENSO)☆

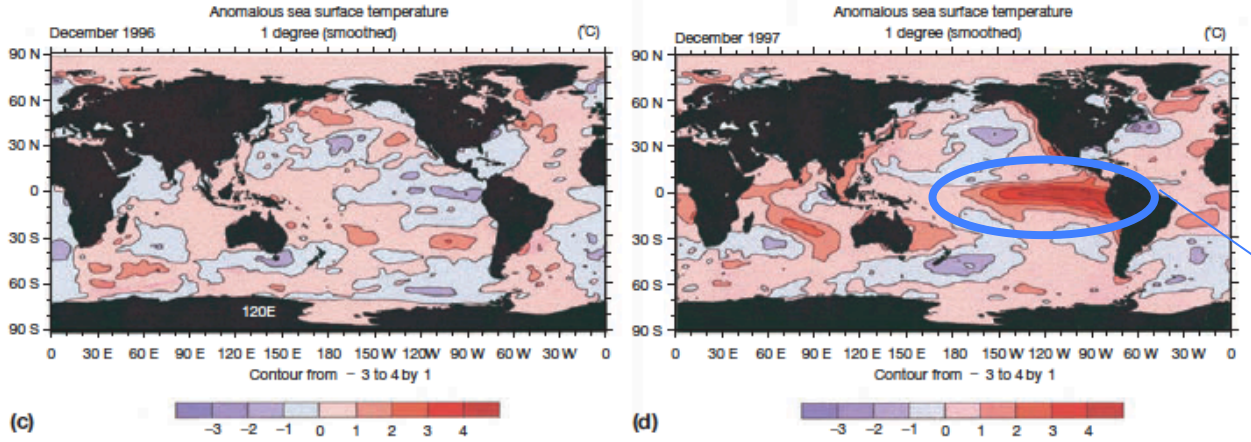
KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA

Con un frequenza variabile dai 3 ai 7 anni le acque superficiali del Pacifico tropicale sono soggette ad un notevole aumento di temperatura.
La variazione inizia nel Pacifico centrale e si propaga verso Est raggiungendo le coste del Pacifico Orientale (El Niño)



SST Dicembre):
1996 (no Niño)
1997 (Niño)

SST: Sea surface temperature



Anomalia SST Dicembre):
1996 (no Niño)
1997 (Niño)

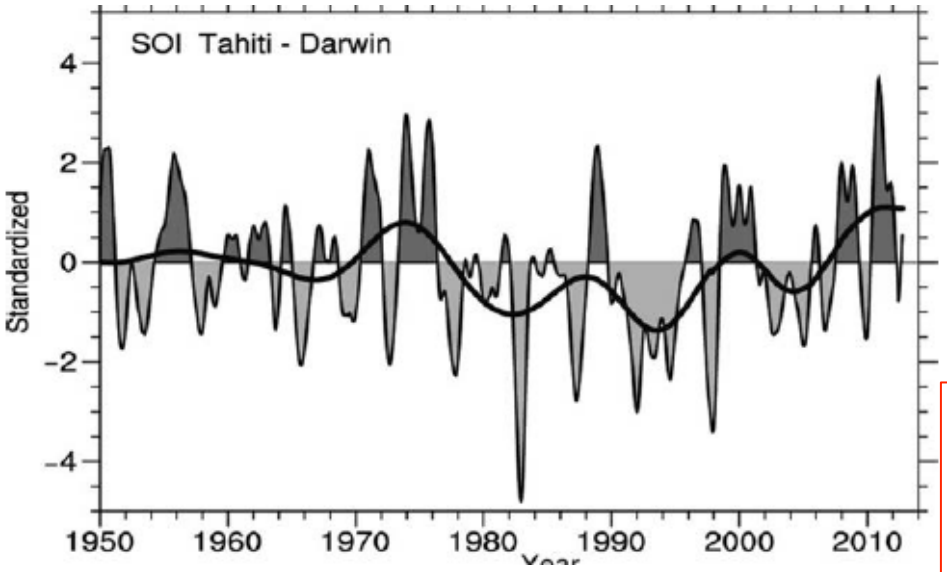
>4°C !!!!!

Eventi ENSO

El Niño Southern Oscillation (ENSO)☆

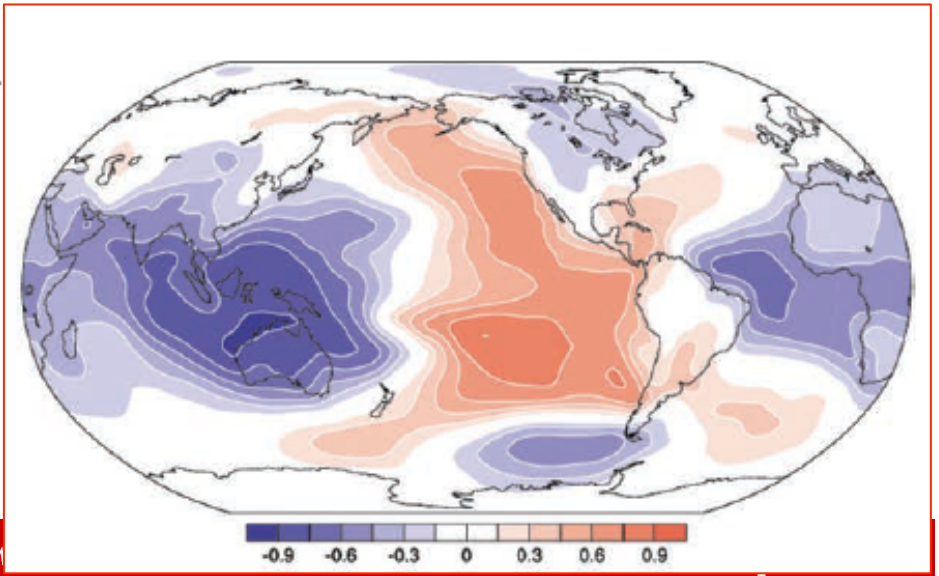
KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA

La “Southern Oscillation (SO) è associata a questa variazione di temperatura misurata dal val
Valore della anomalia della differenza di pressione atmosferica fra Darwin e Tahiti, che costituisce il “Southern Oscillation Index” (SOI)



SOI Index 1950-2010

Correlazione SOI Index/pressione atmosferica



Eventi ENSO

El Niño Southern Oscillation (ENSO)☆

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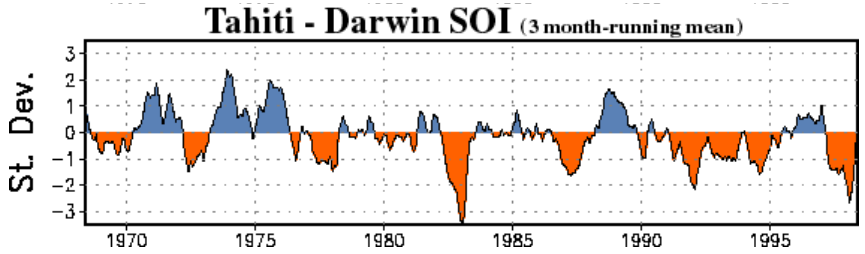
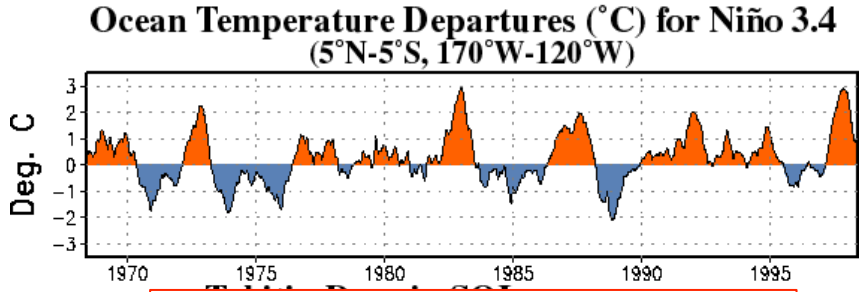
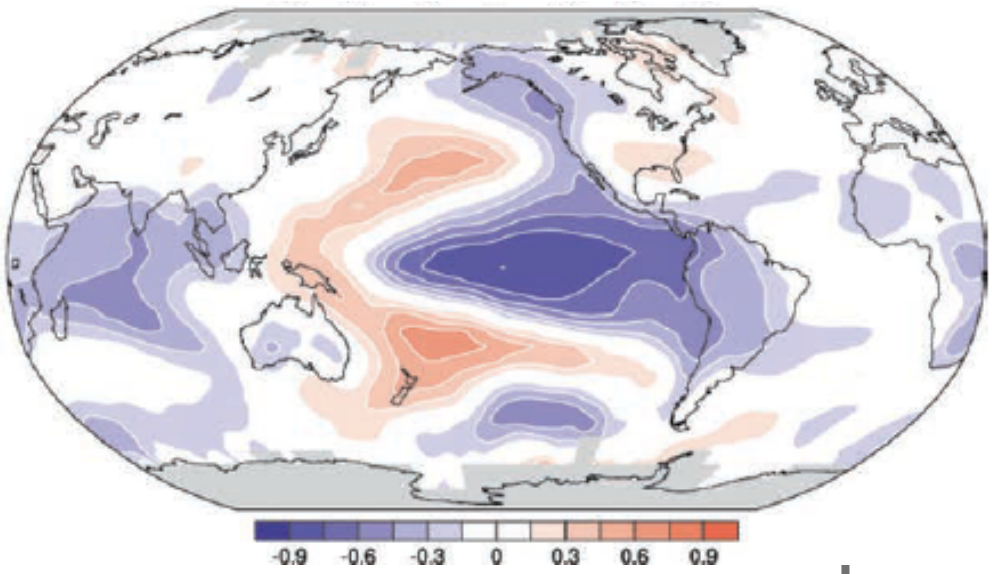


SOI 1968-2000



Anomalia SST pacifico tropicale

Correlazione SOI/anomalia SST

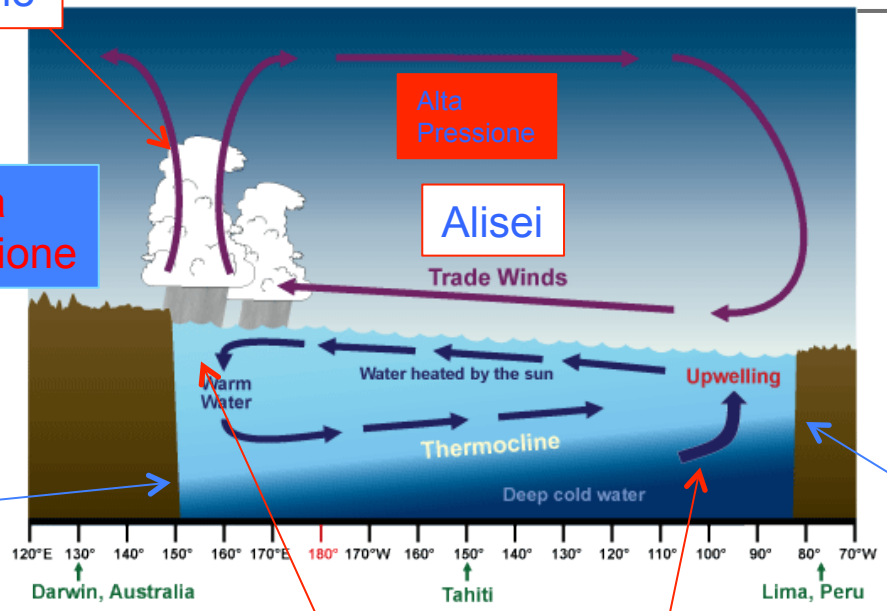


Eventi ENSO
Fase neutrale

Ascensione aria
Calda e umida
Condensazione
e precipitazione

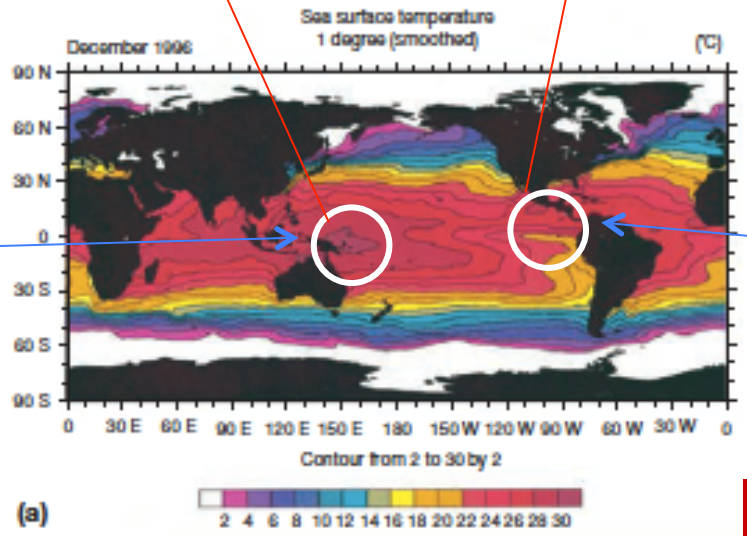
El Niño Southern Oscillation (ENSO)☆

KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA



Termoclino
"profondo"

Termoclino
"superficiale"



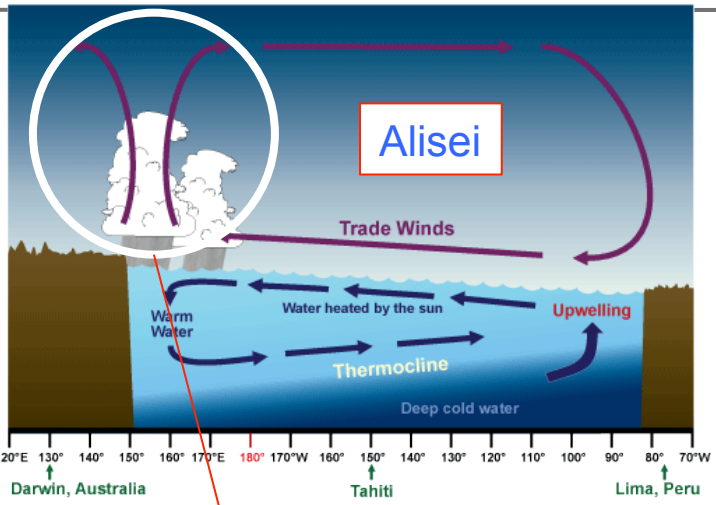
"Warm pool"
Massime SST
Dell'Oceano

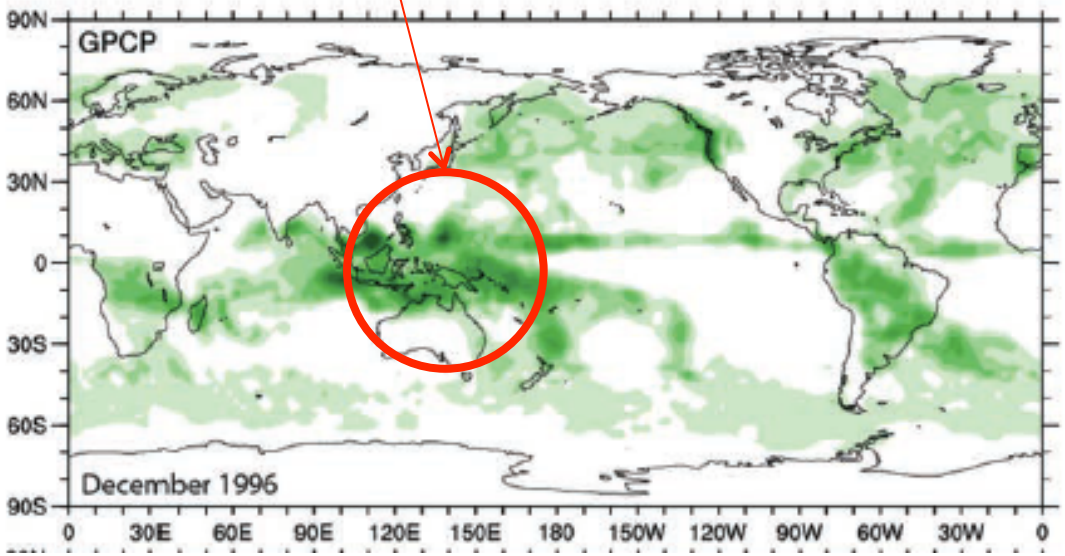
Risalita acque
Profonde
(<SST)

Eventi ENSO
Fase neutrale

El Niño Southern Oscillation (ENSO)☆

KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA





Precipitazioni Dicembre 1996 (condizioni

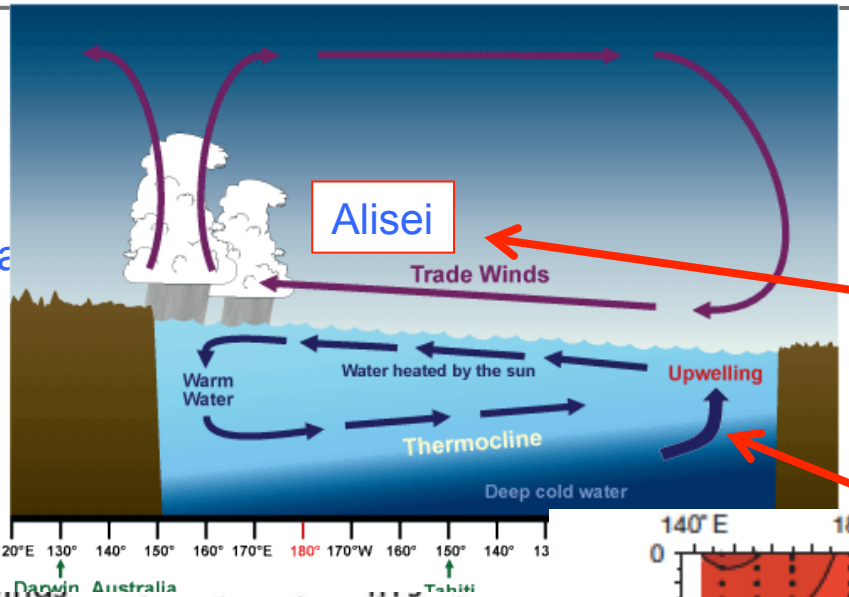
Neutrali)

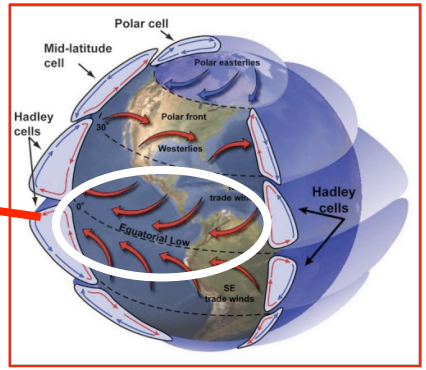
Eventi ENSO
Fase neutrale

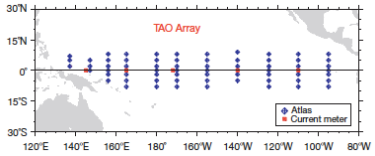
El Niño Southern Oscillation (ENSO)☆

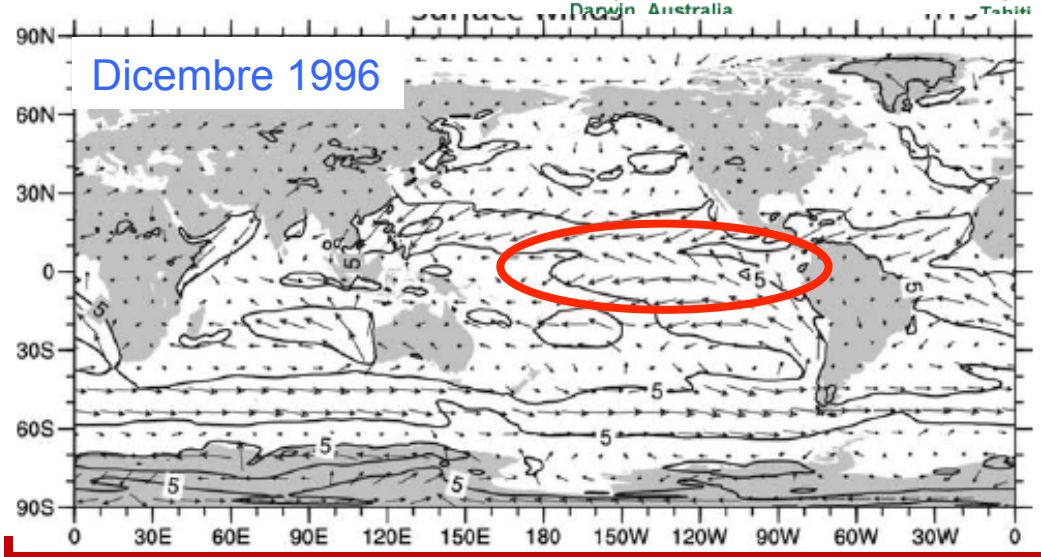
KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA

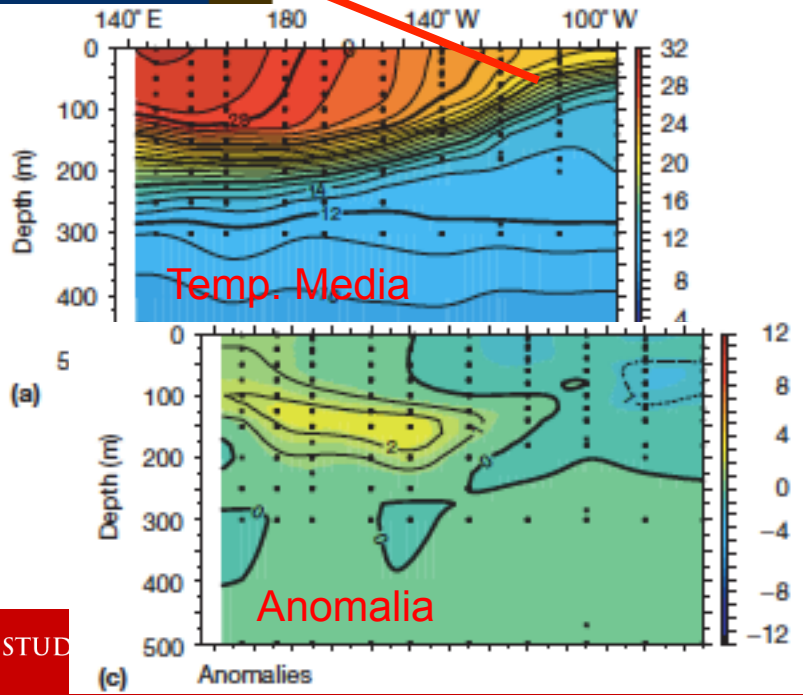
I venti superficiali governano ilmovimento delle acque superficiali, la loro divergenza e quindi anche la risalita di Acque profonde











Eventi ENSO Fase "Calda"

El Niño Southern Oscillation (ENSO)☆

KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA

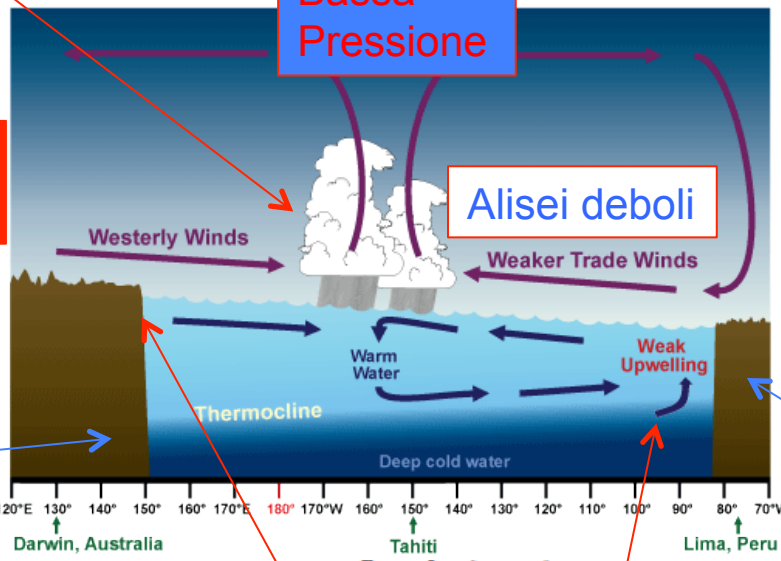
"El Niño"

Ascensione aria
Calda e umida
Condensazione
e precipitazione

Bassa Pressione

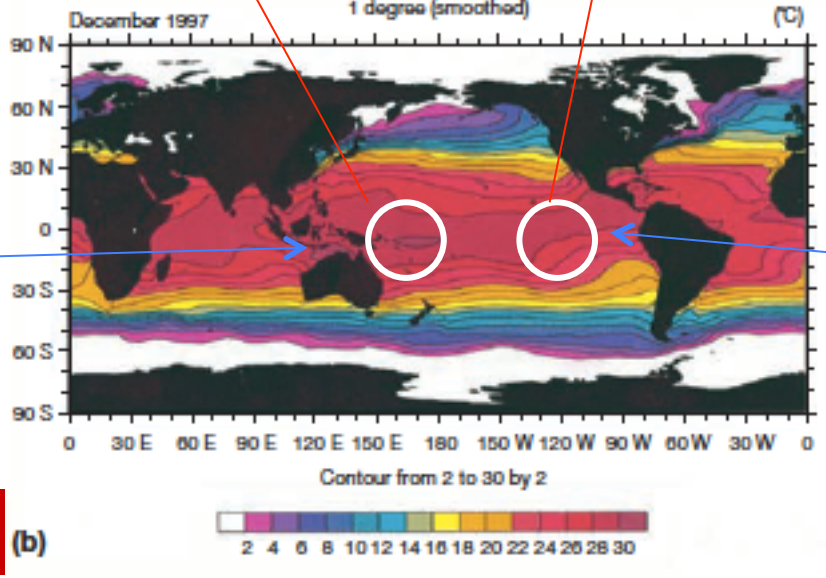
Alta Pressione

Alisei deboli



Termoclino meno "profondo"

Termoclino meno "superficiale"



"Warm pool"
Massime SST
Dell'Oceano

Minor Risalita acque
Profonde
(>SST)

Eventi ENSO
Fase "Calda"

El Niño Southern Oscillation (ENSO)☆

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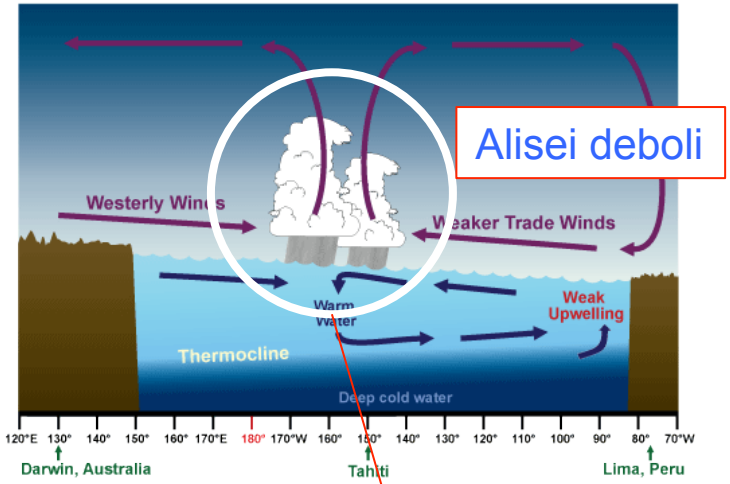
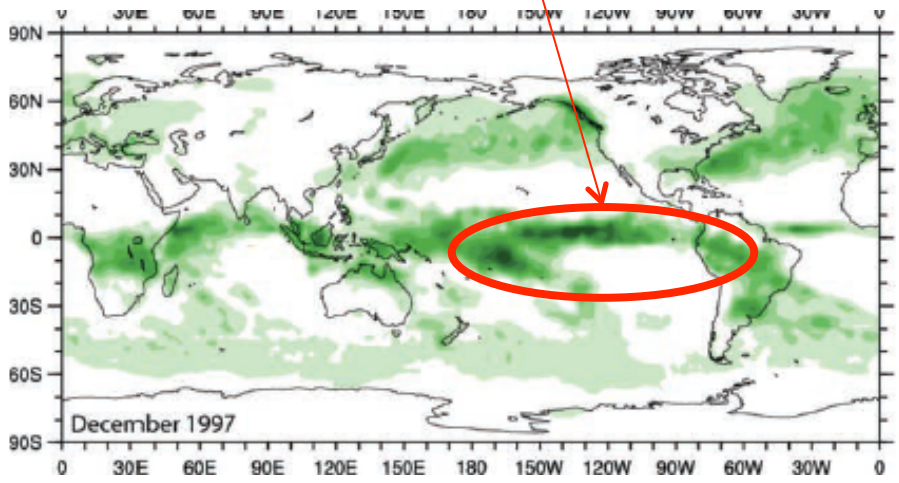
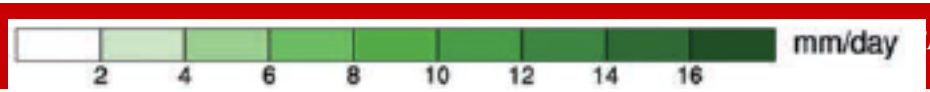


"El Niño"



Precipitazioni Dicembre 1997 (condizioni

Niño)

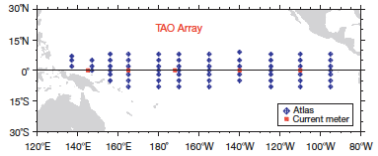


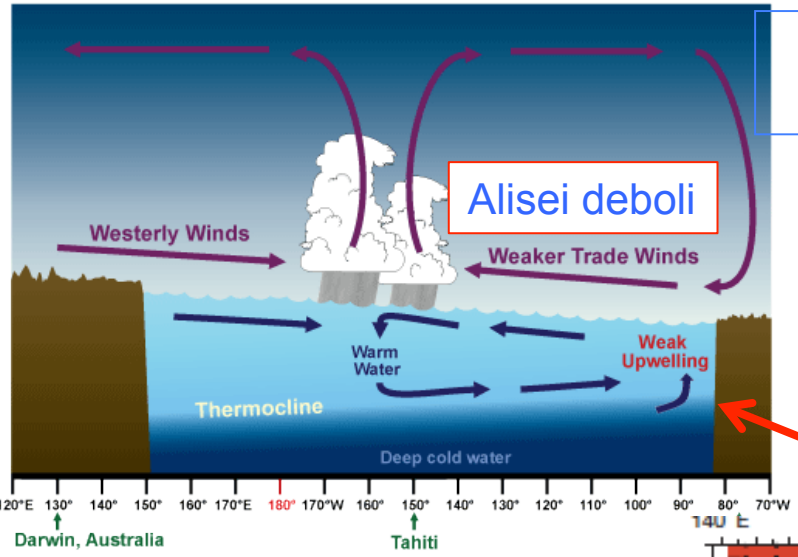
Eventi ENSO
Fase "Calda"

El Niño Southern Oscillation (ENSO)☆

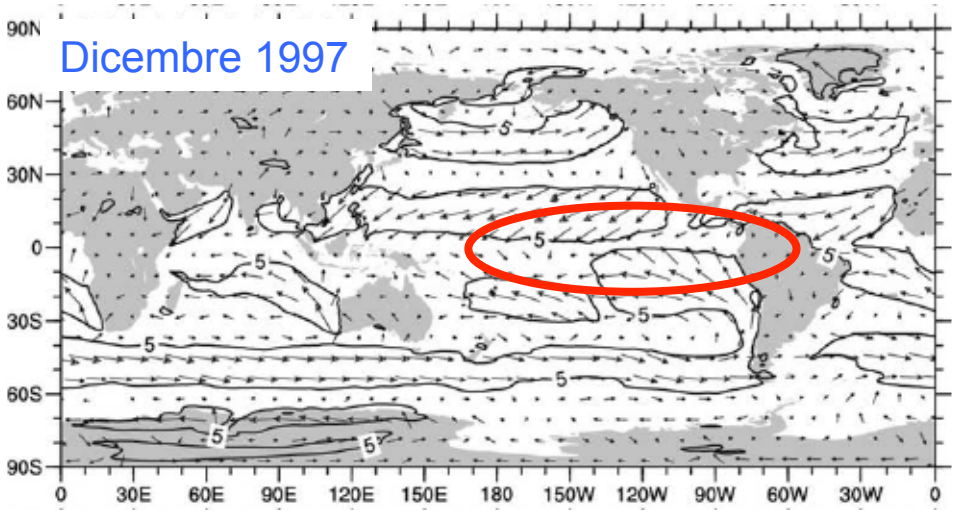
KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA

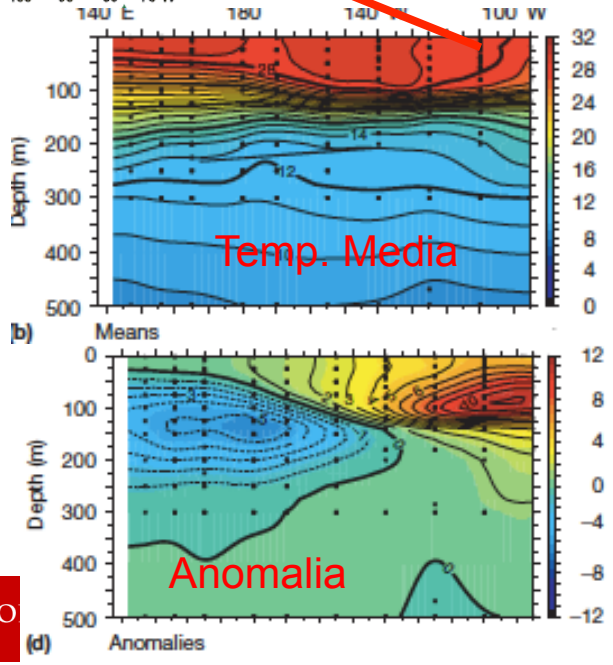
I venti superficiali governano ilmovimento delle acque superficiali, la loro divergenza e quindi anche la risalita di Acque profonde





"El Niño"





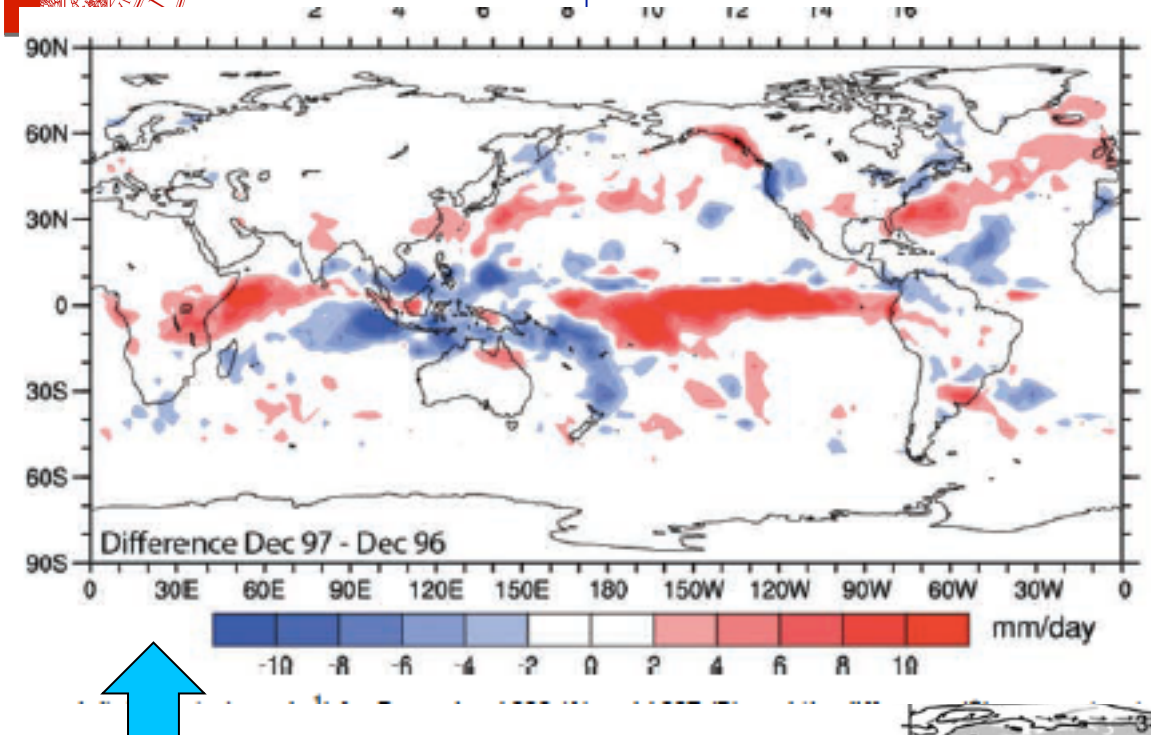
Eventi ENSO
Fase "Calda"

El Niño Southern Oscillation (ENSO)☆

KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA

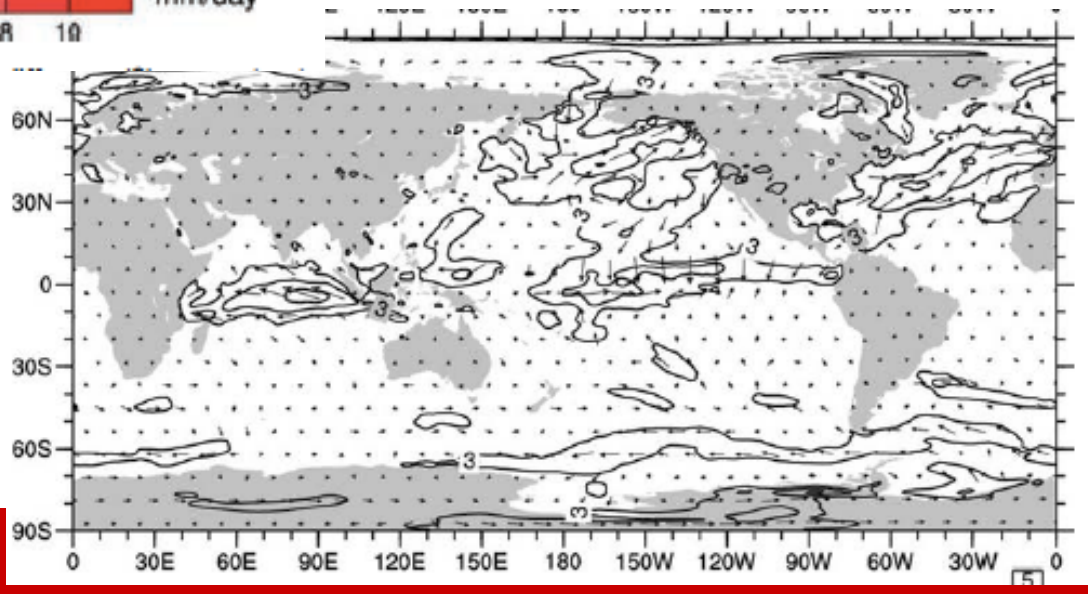
"El Niño"

Differenza
Dic 97-Dic 96



Precipitazioni

Venti Superficiali

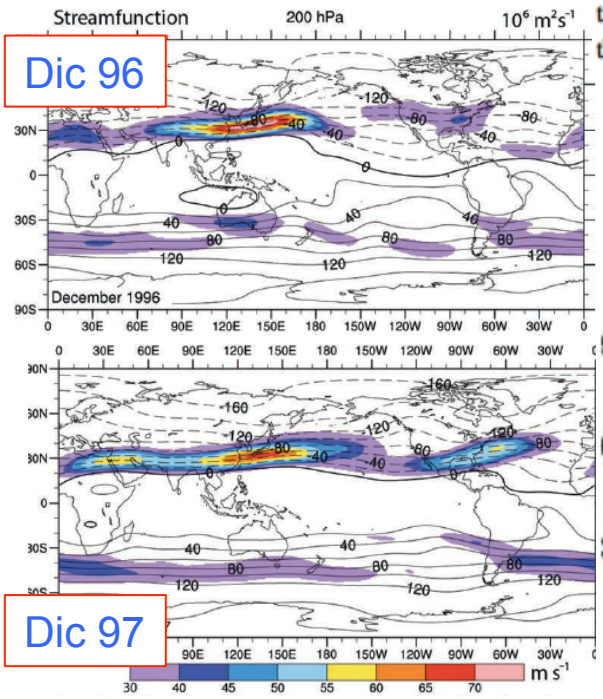


"El Niño"

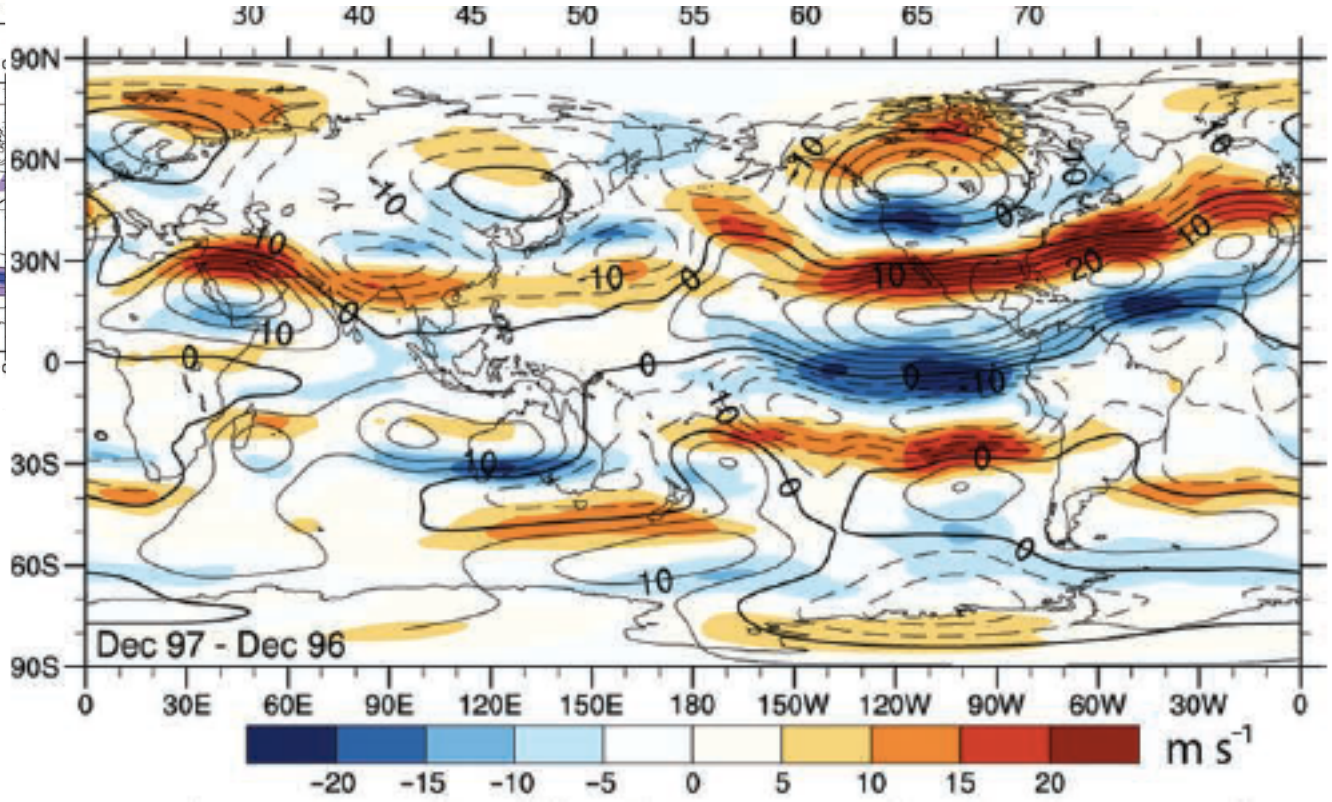
Eventi ENSO
Fase "Calda"

El Niño Southern Oscillation (ENSO)☆

KE Trenberth, National Center for Atmospheric Research, Boulder, CO, USA



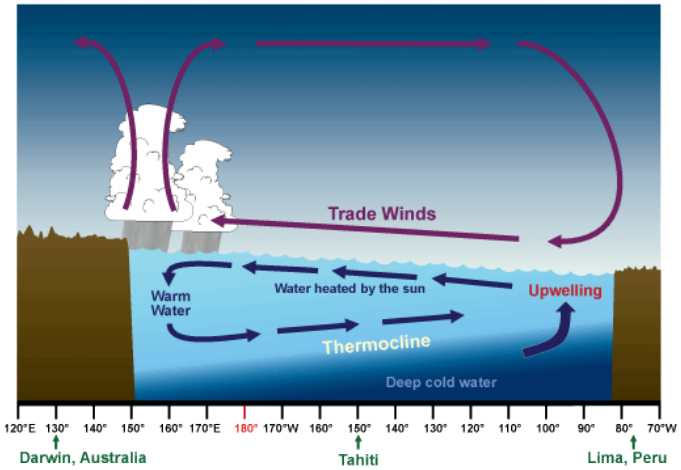
trade winds completes the positive feedback cycle leading to an El Niño event. The shifts in the location of the organized rainfall in the tropics and the latent heat released alters the heating patterns of the atmosphere. Somewhat like a rock in a stream of water, the anomalous heating sets up waves in the atmosphere that extend into midlatitudes altering the winds and changing the jet stream and storm tracks (e.g., Figure 8). Note especially the strong westerly jets in the Pacific of both hemispheres, and in the Northern (winter) Hemisphere the jet stream in December 1997 extends into California and across the southern United States, carrying with it disturbances that result in extensive rains. Weaker westerlies exist farther north and so the overall storm track shifts towards the equator in the Pacific.



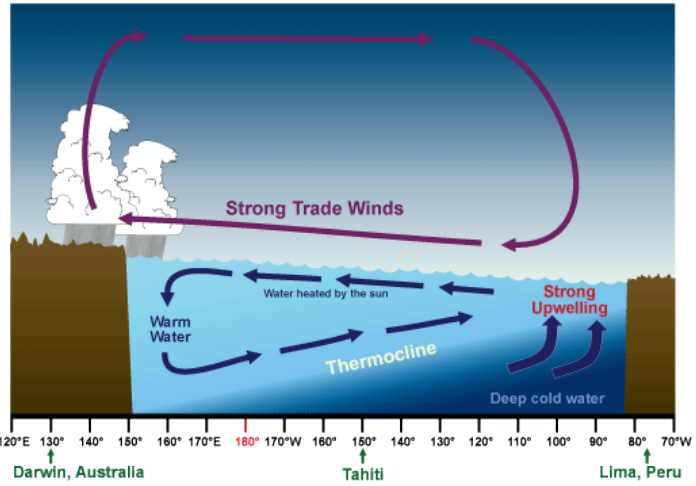
Differenza
Dic 97-Dic 96
Stream function
E vento in quota

Eventi ENSO
Fase “Fredda”

Neutral



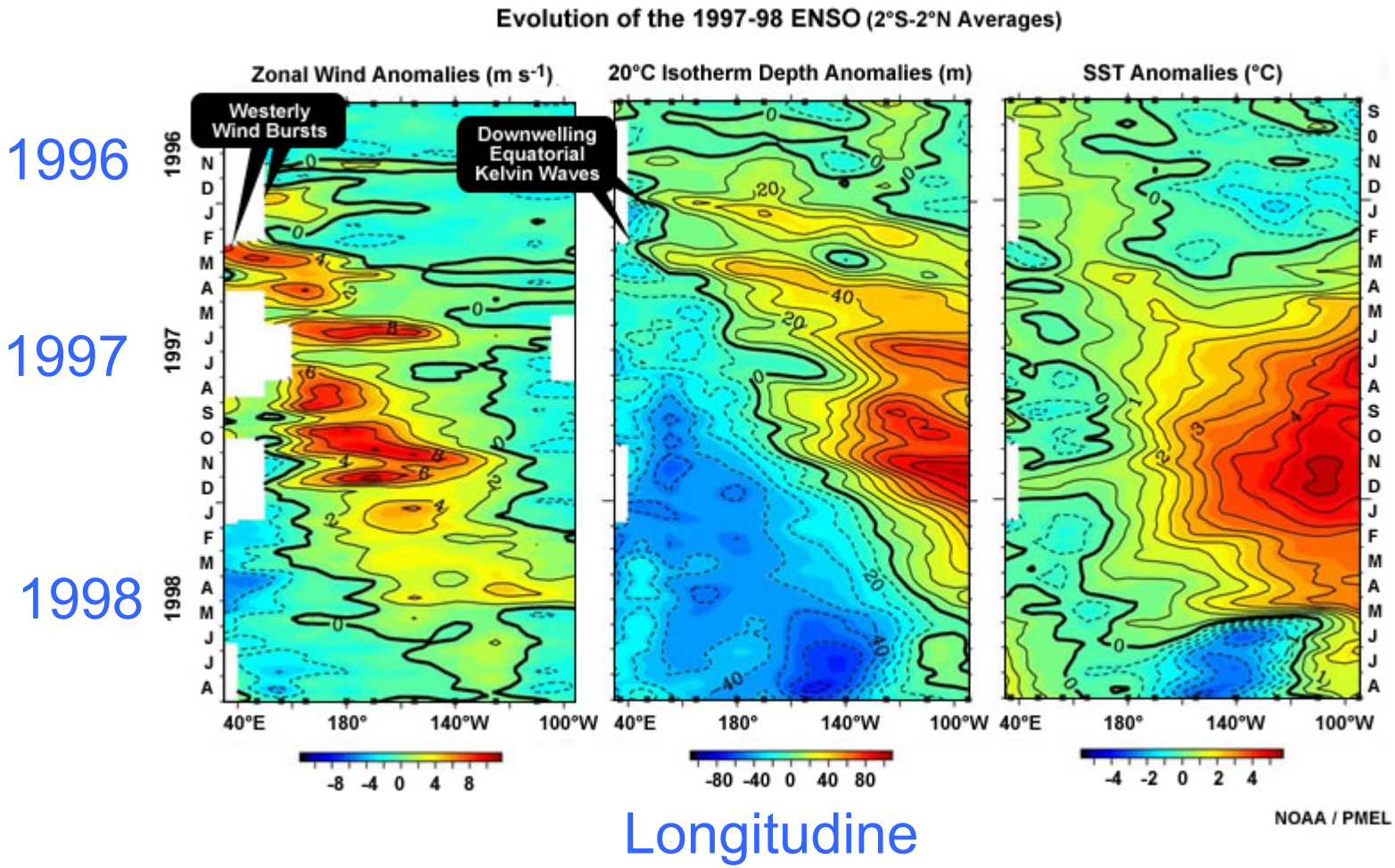
“La Niña”



Un rafforzamento generale delle caratteristiche della fase “neutrale”

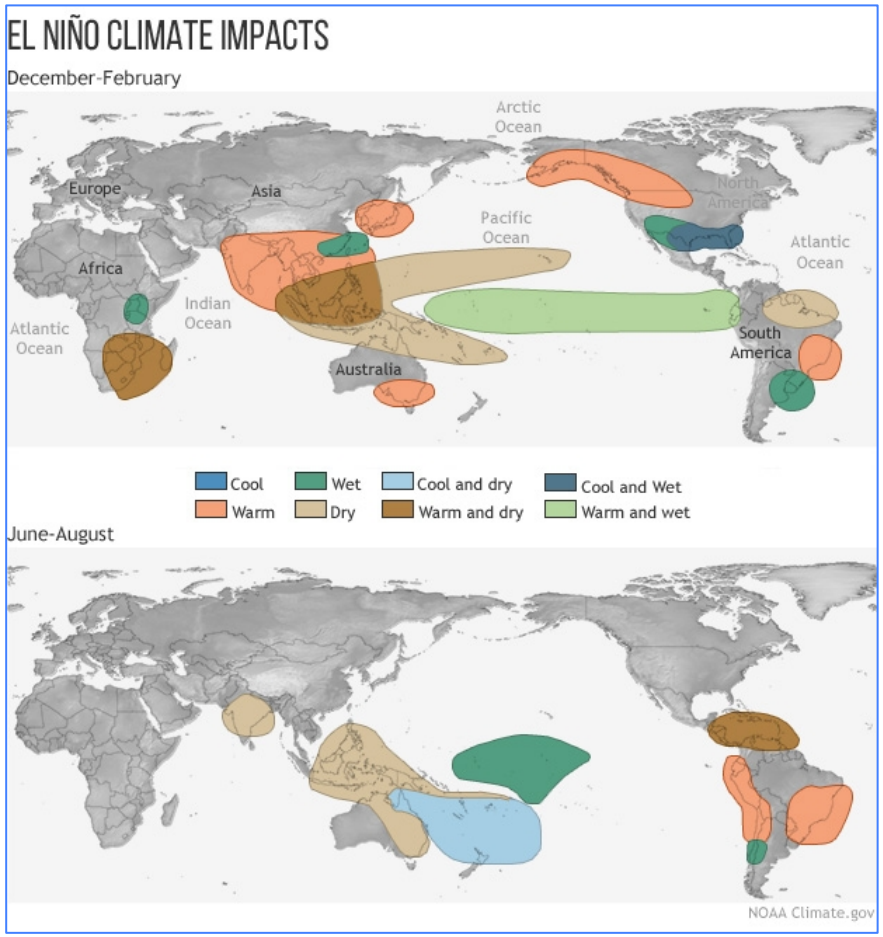
Eventi ENSO
Evoluzione temporale

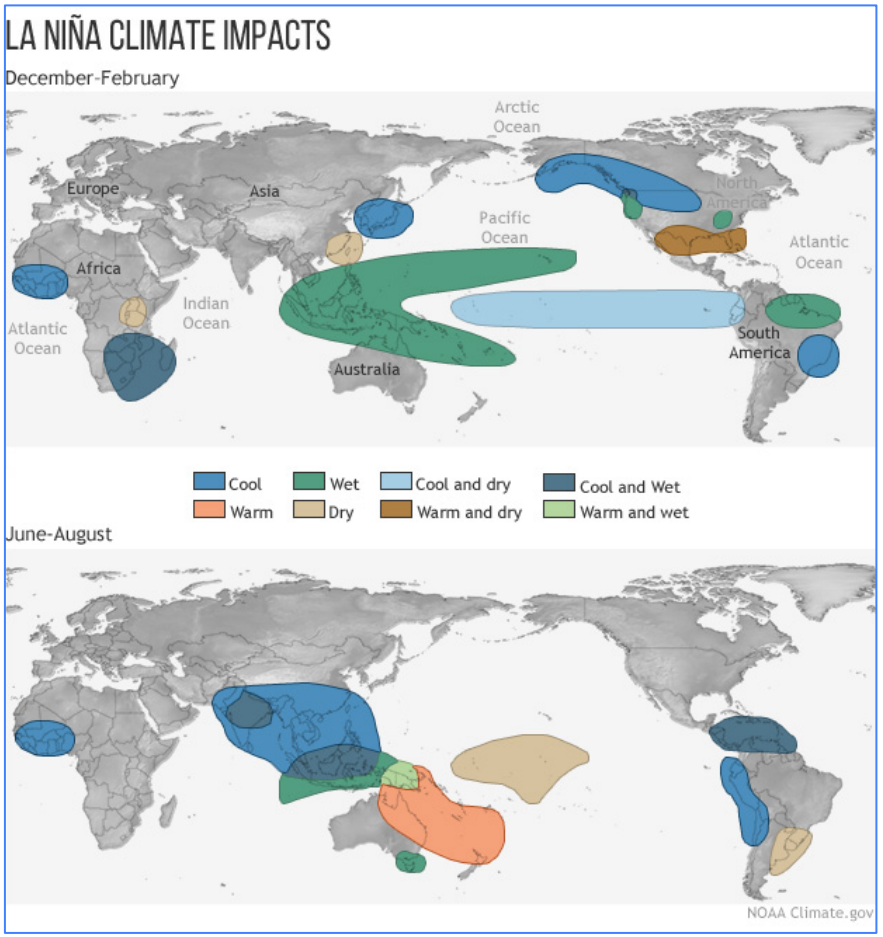
http://www.goes-r.gov/users/comet/tropical/textbook_2nd_edition/print_versions.htm



Longitudine

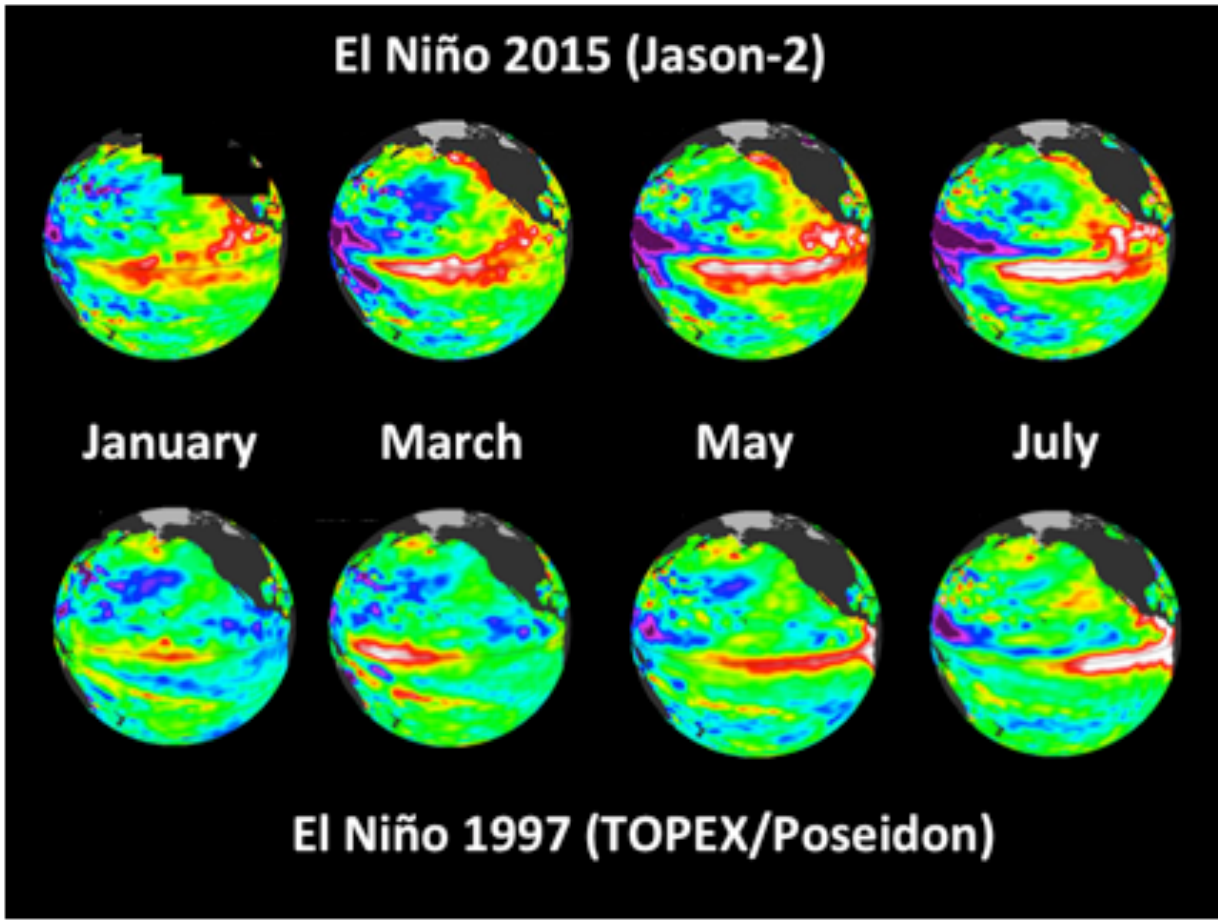
Eventi ENSO
Impatto





Eventi ENSO 1997 & 2015
Evoluzione temporale

Jet Propulsion Laboratory
California Institute of Technology

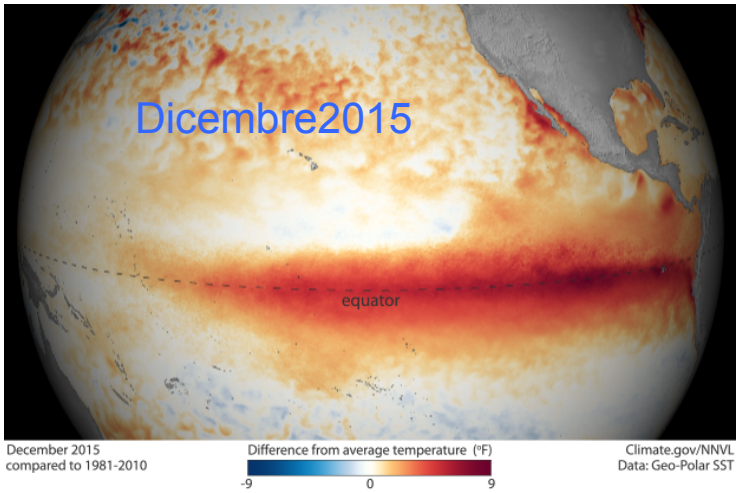


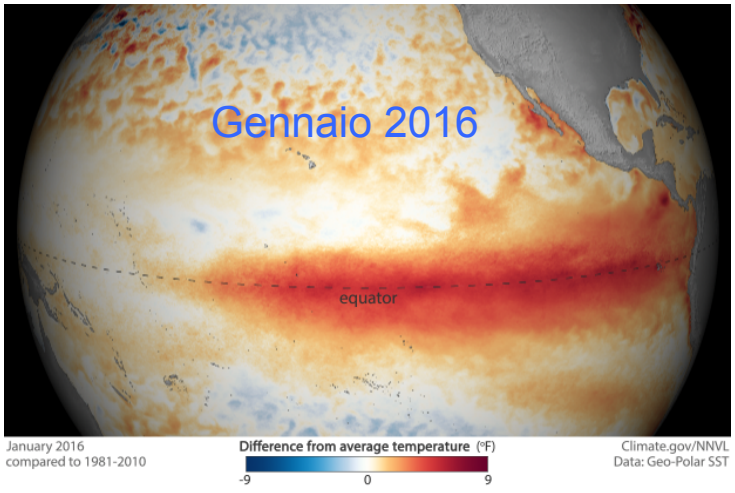
nalies had already appeared. Figure 2 shows the progression of sea level
nalies for 1997 and 2015 from January to July. During the development of
1997 El Niño large anomalies were not visible in the Eastern Equatorial
ific until July. This year (2015) has shown large anomalies of over 20 cm
dominating the Equatorial Pacific since January.

https://podaac.jpl.nasa.gov/animations/ElNi%C3%B1o_Watch_2015

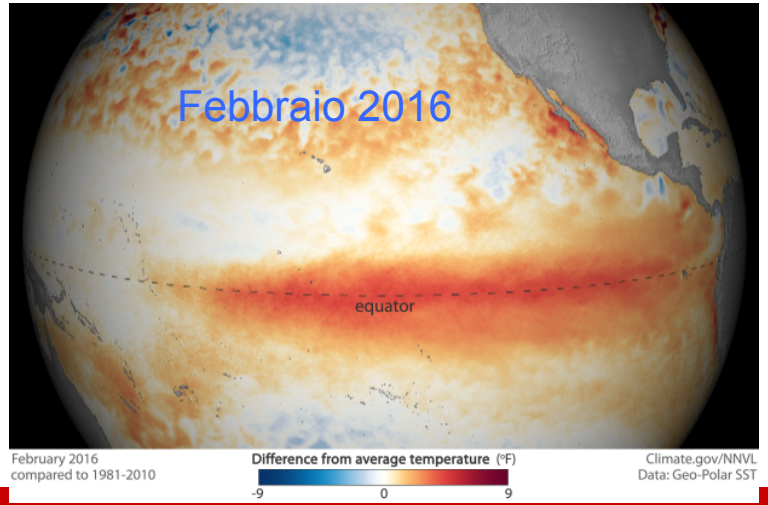
ENSO 2015-2016
Stato attuale

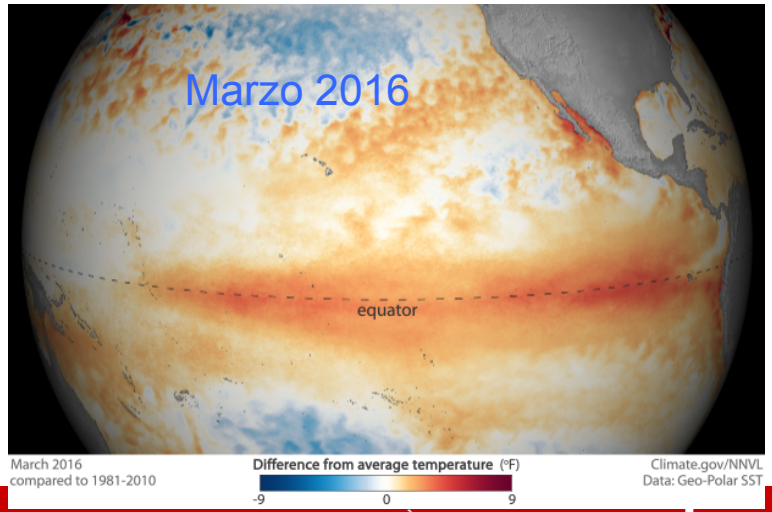
Climate.gov
science & information for a climate-smart nation





Anomalia SST

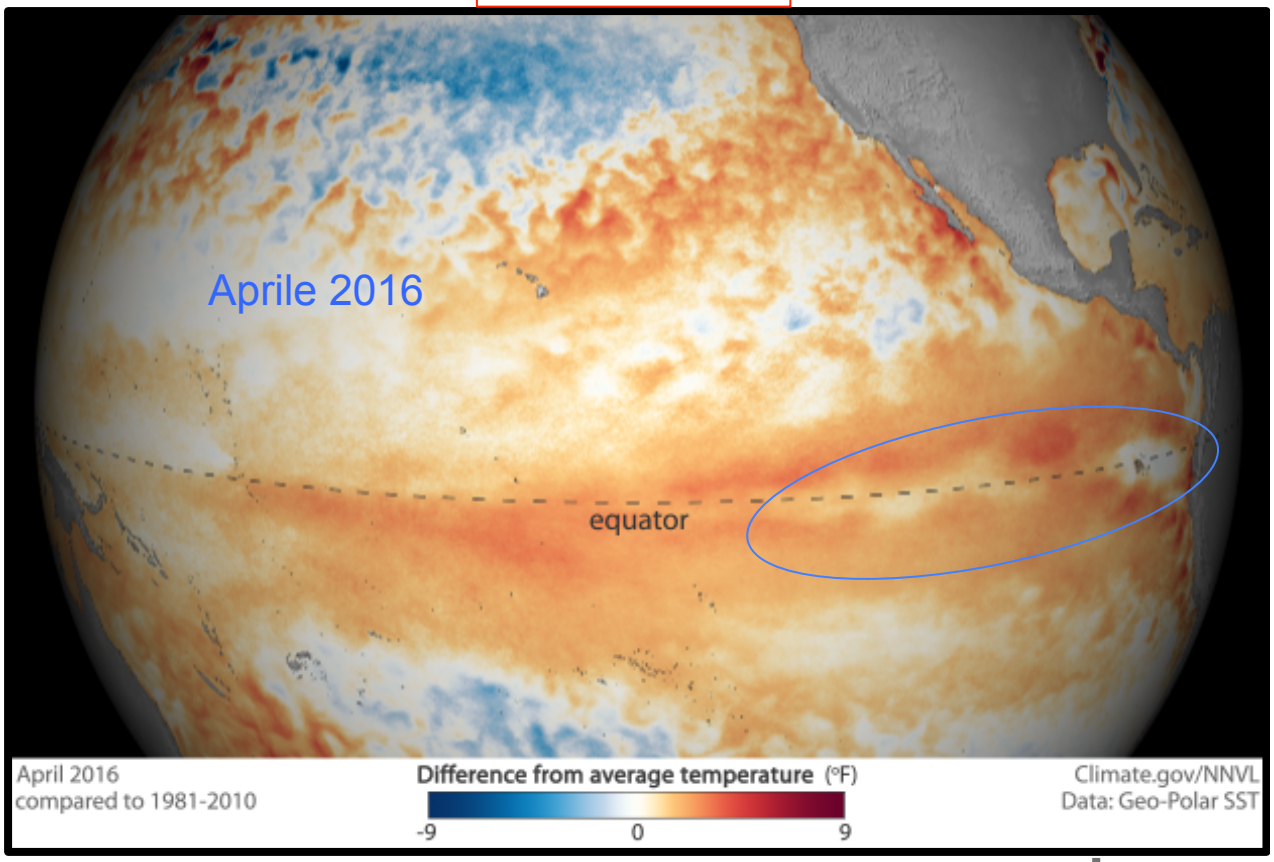




ENSO 2015-2016
Stato attuale

El Niño is still hanging around, and it's expected to continue through spring or early summer, but the impact on U.S. weather during this transition season is usually minor. Meanwhile, NOAA issued a La Niña Watch: conditions are favorable for La Niña to emerge within 6 months.
In particular, heat content in the central Pacific dropped below average in March for the first time in a year.
NOAA's next ENSO update will be released on May 12.

Anomalia SST



ENSO 2015-2016
Stato attuale

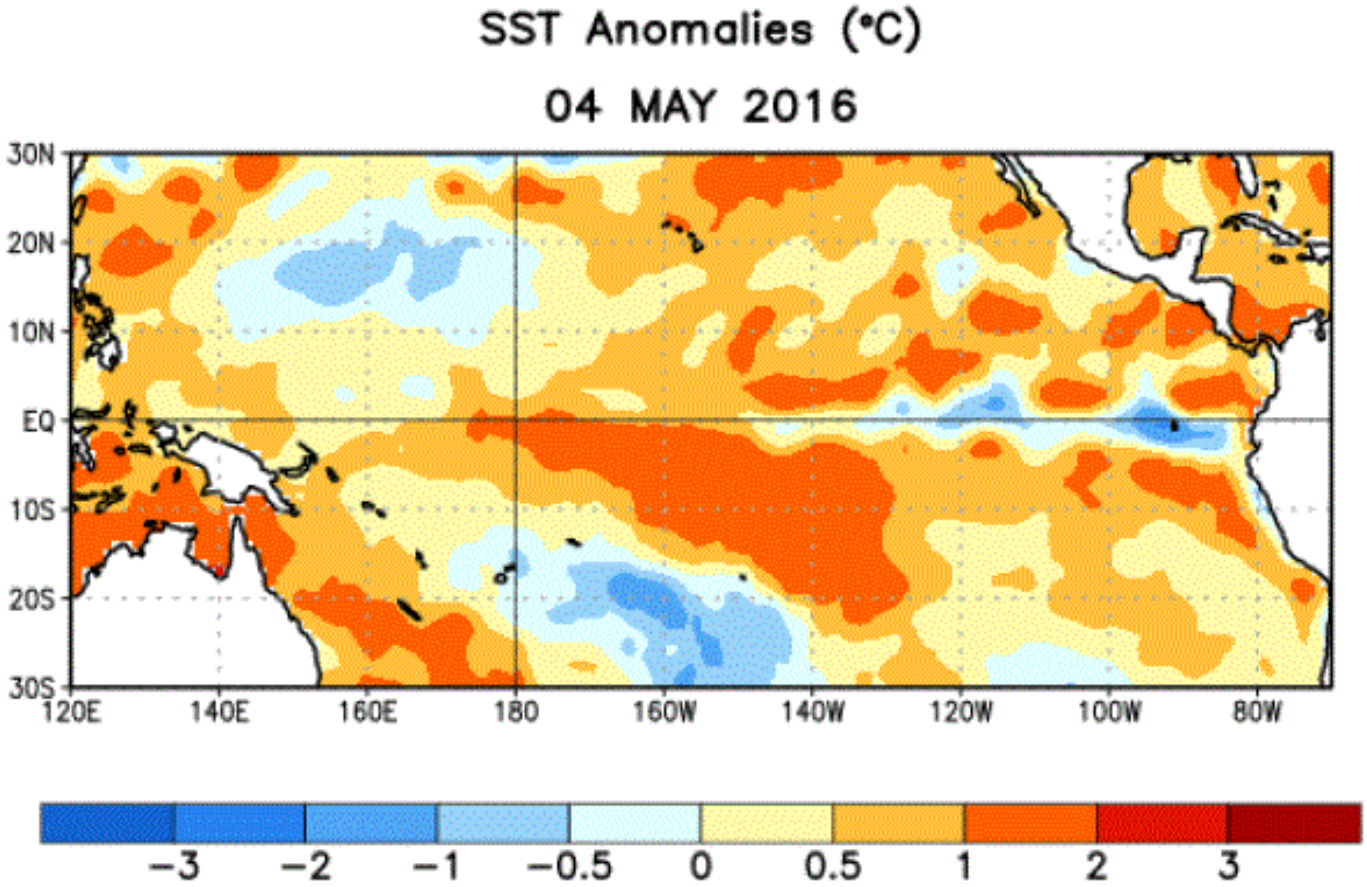
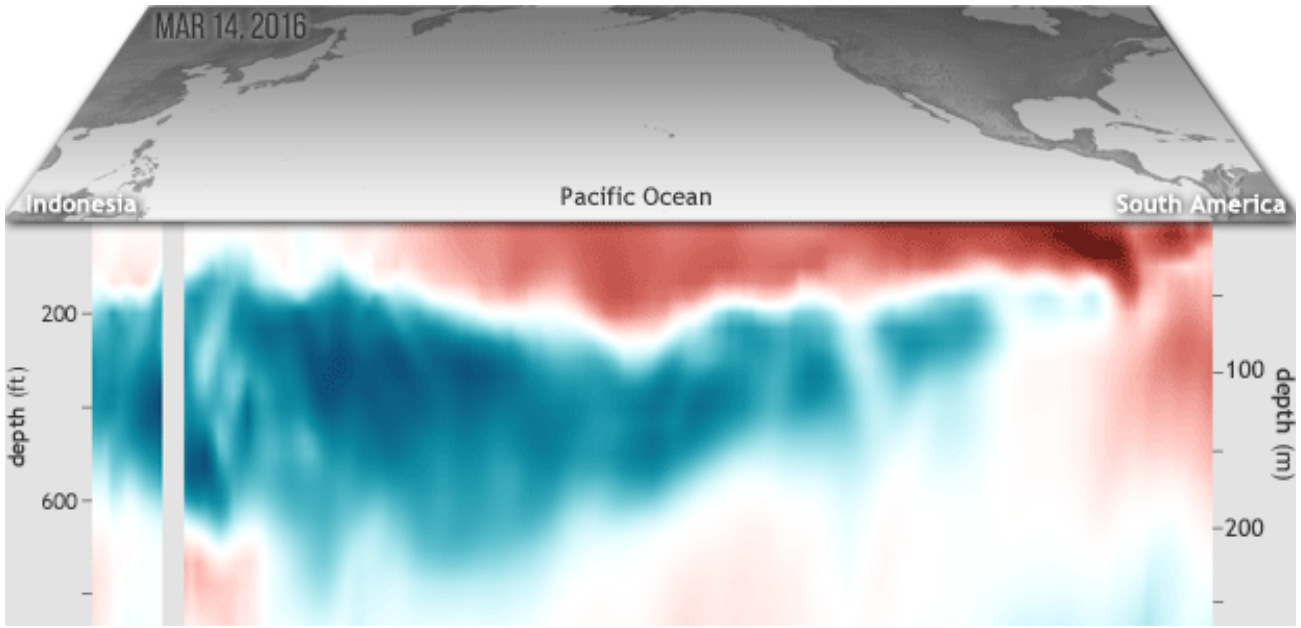


Figure 1. Average sea surface temperature (SST) anomalies (°C) for the week centered on 4 May 2016. Anomalies are computed with respect to the 1981-2010 base period weekly means.

ENSO 2015-2016
Stato attuale



La Niña coming? Deep pool of cool water is making its way across tropical Pacific

Monday, May 16, 2016

This animated gif shows where temperatures in the top 300 meters of the Pacific Ocean at the equator were warmer or cooler than average during 5-day periods centered on three dates this spring: March 14, April 13, and May 3.

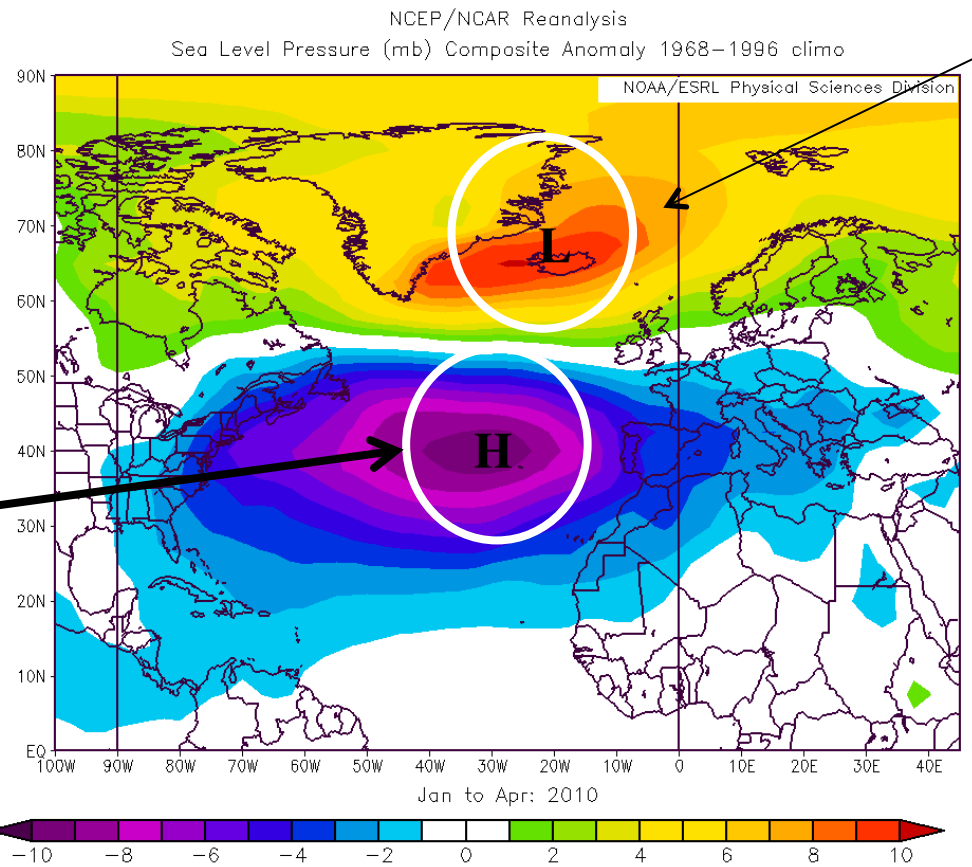
As the weeks pass, the layer of warm water at the surface contracts to the central Pacific and becomes very shallow, a sign that the current El Niño is on its way out.

By the final frame of the animation, the cold pool is just breaching the surface of the eastern Pacific off South America.

North Atlantic Oscillation (NAO)

Il sistema di pressione atmosferica sull'Oceano Atlantico Settentrionale

"Icelandic Low"
Ciclone Islandese



"Azores High"
Anticiclone delle
Azzorrre

:

North Atlantic Oscillation (NAO)

Oscillazione nord-Atlantica (North Atlantic Oscillation, NAO)
Un modo di variazione su naturale su larga scala del clima con importanti conseguenze
Sul tempo e siul clima della regione Nord-Atlantica (Europa in particolare.
NAO è presente in tutte le stagioni, ma è particolarmente importante durante l'inverno.

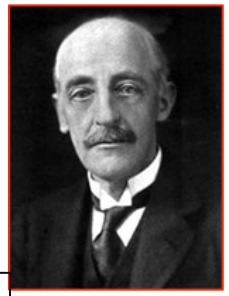
Consiste in una variazione zonale (Nord ⟷ Sud) del percorso delle perturbazioni attraverso il nord-Atlantico verso l'Europa .

CORRELATION IN SEASONAL VARIATIONS OF WEATHER, VIII.

A PRELIMINARY STUDY OF WORLD-WEATHER

BY

Gilbert T. Walker, C.S.I., M.A., Sc.D., Ph.D., F.R.S.



It is generally recognised that an accentuated pressure difference Between Azores and Iceland in autumn and winter is associated with [….] high temperature in winter and spring in Scandinavia and the East coast of the United States and with lower temperatures in the east Coasto of Canada and the west coast of Greenland.

Idetntificata nel 1924 da Sir Gilbert Walker
Sempre lui…….

North Atlantic Oscillation (NAO)

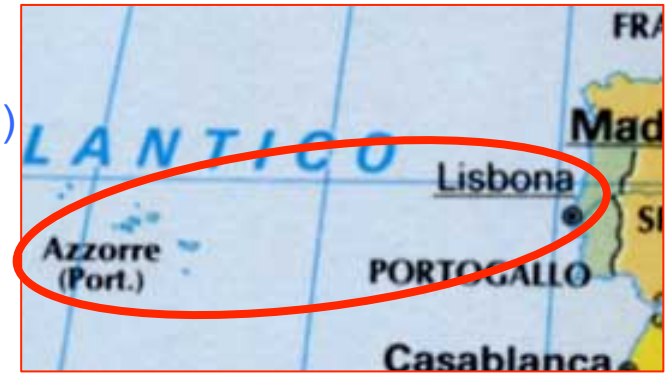
…an accentuated pressure difference between Azores and Iceland……

Una misura della differenza di pressione atmosferica fra il nord atlantico setterntrionale (Islanda) E il nord Atlantico meridionale (Azzorre); il NAO index.

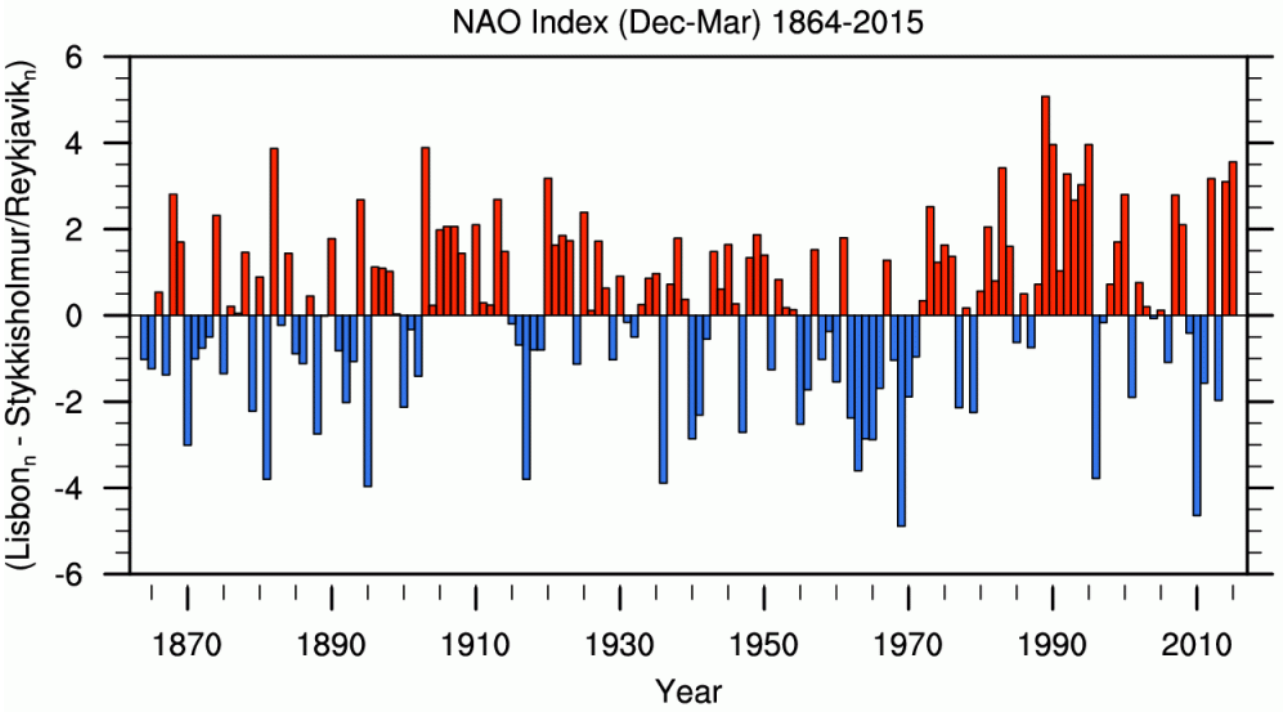
Differenza di pressione Invernale (Normalizzata) calcolata fra i valori di pressione atmosferica misurata a

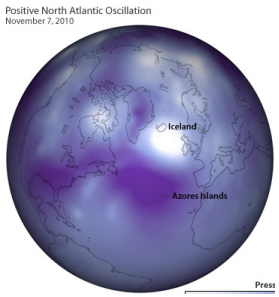
Stykkisholmur/Reykjavik,

Ponta Delagada (azzorre) o Lisbona



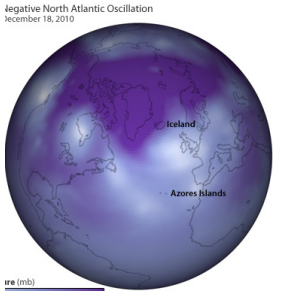
North Atlantic Oscillation (NAO)





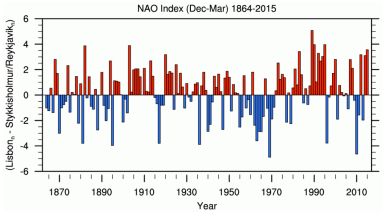
NAO index>0:
NAO in fase positiva

NAO index<0:
NAO in fase Negativa

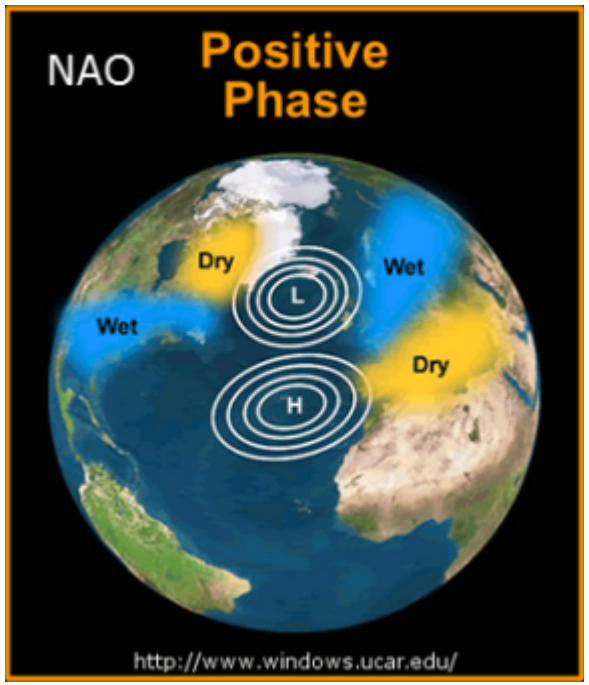


$$I_{NAO} = \frac{p_{Lisbona} - p_{\text{Reykjavik,}}}{\left\langle p_{Lisbona} - p_{\text{Reykjavik,}} \right\rangle} = \frac{\Delta p}{\langle \Delta p \rangle}$$

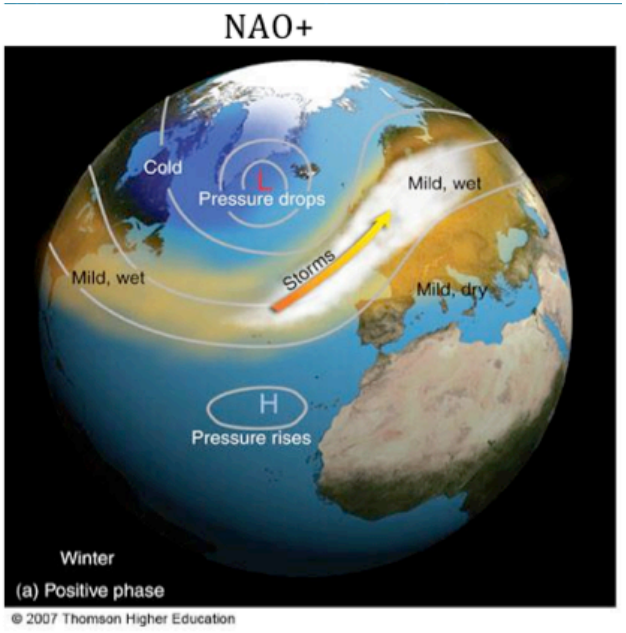
North Atlantic Oscillation (NAO)



NAO index>0:
NAO in fase positiva

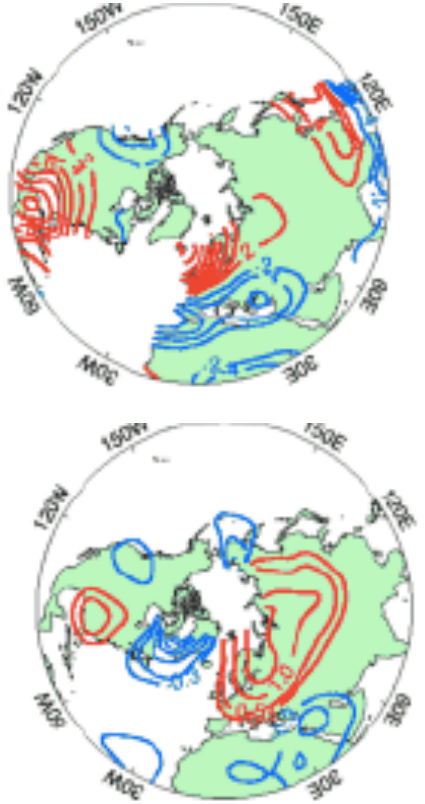


Forte differenza di pressione



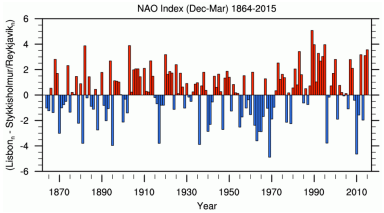
Aria calda e umida verso
l'Europa del nord

Anomalia precipitazioni



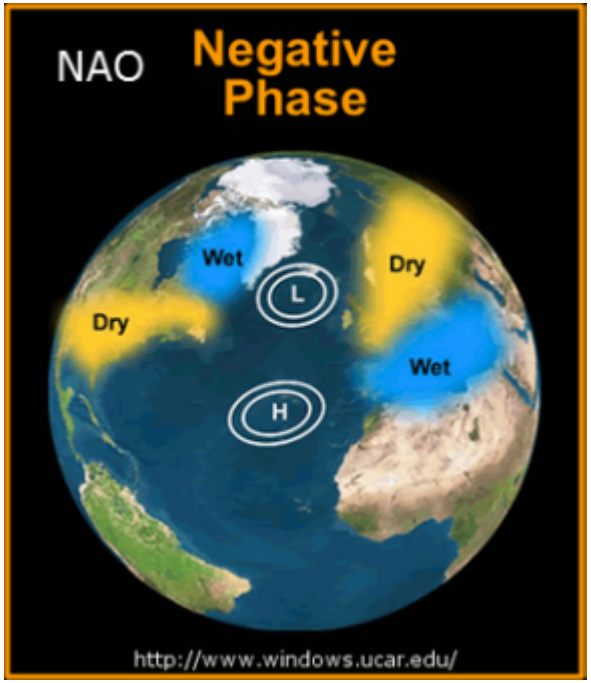
Anomalia temperatura

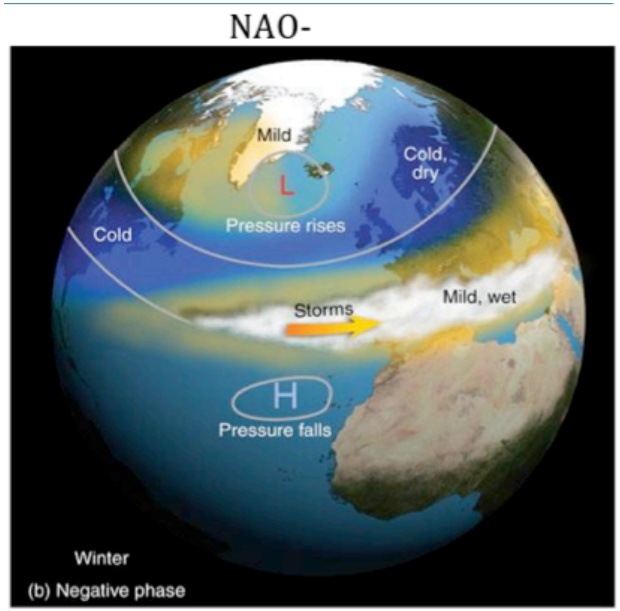
North Atlantic Oscillation (NAO)

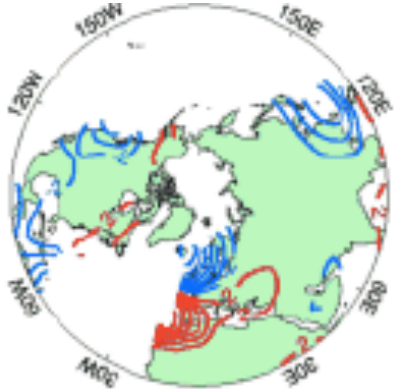


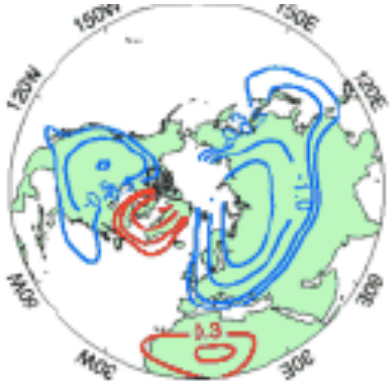
NAO index<0:
NAO in fase Negativa

Anomalia precipitazioni









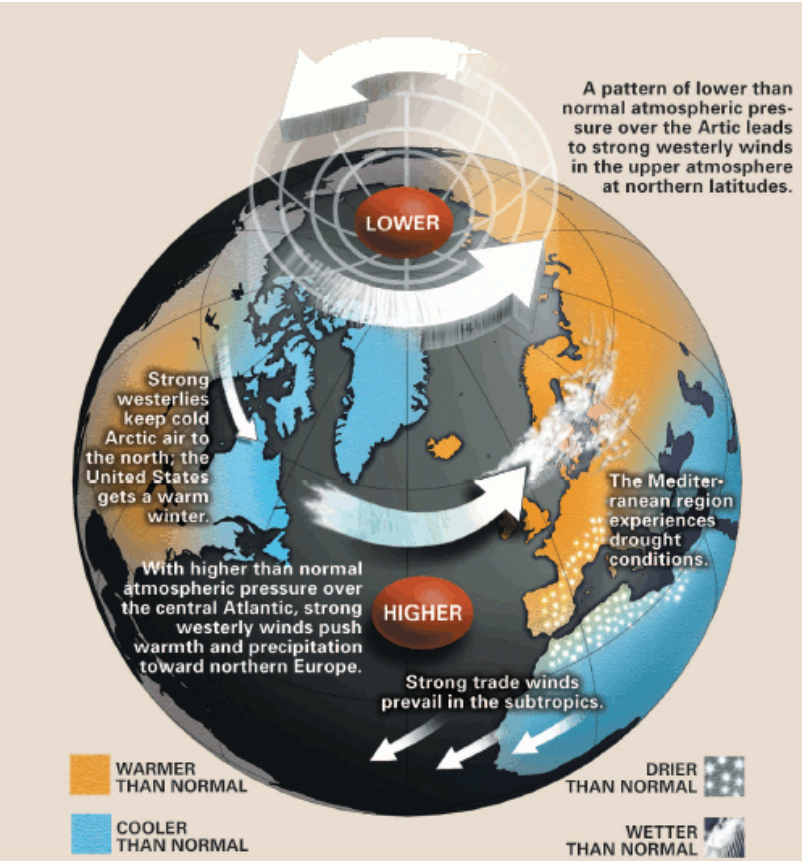
Ridotta differenza di pressione

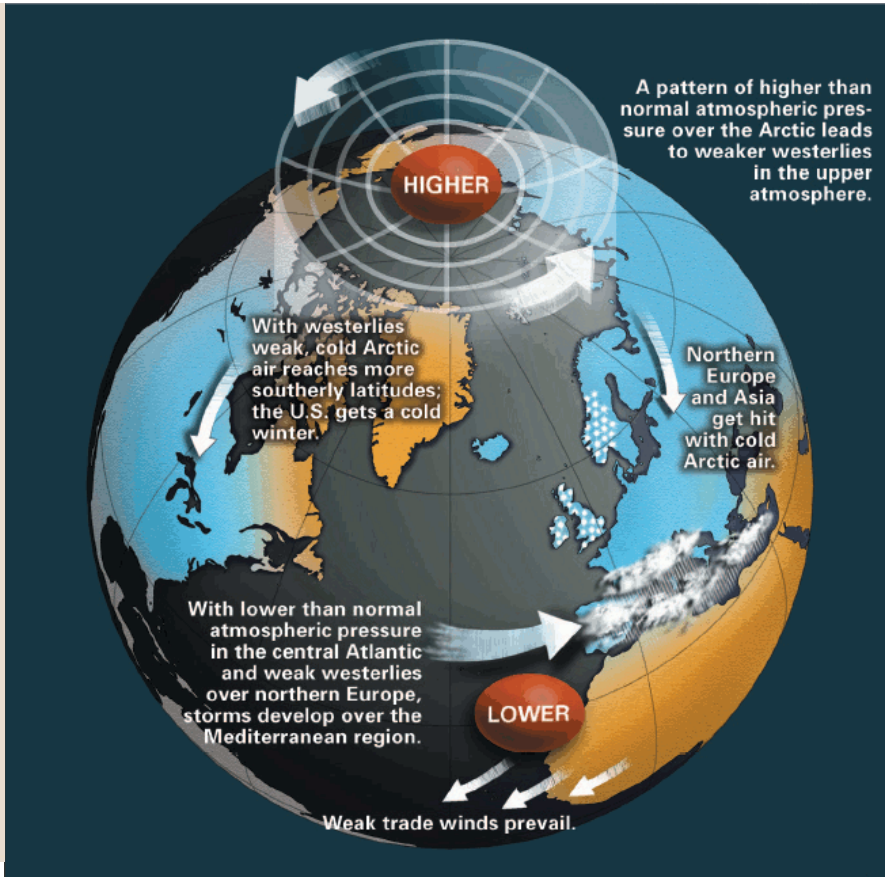
Aria calda e umida verso l'Europa del sud e Mediterraneo

Anomalia temperatura

North Atlantic Oscillation (NAO)

NAO collegata con oscillazioni della pressione atmosferica nella regione polare (Arctic Oscillation, AO)





AO Negativa: NAO Positiva
AO-→NAO+

AO Positiva: NAO Negativa
AO+→NAO-